THE ENGINEER

DECEMBER 19, 1952

Centenary of Leeds Waterworks

WE have received a brochure commemorating the centenary of the Leeds Corporation water undertaking, in which a history of the water supply to that city is given. Although the supply of water to Leeds began in 1693, it is only for the past hundred years that the water undertaking has been owned by the Corporation. At the end of last March the undertaking's statutory area of supply extended over 109 square miles, with an estimated population of nearly 510,000; the average daily consumption was nearly 22 m.g.d. at that time. The sources of supply are the Washburn and Ure valleys and five storage reservoirs have been constructed at various times in these valleys. The largest of them is the Eccup reservoir, which has a storage capacity of 1410 m.g., but Leighton reservoir is nearly as large with a capacity of 1050 m.g. Eccup reservoir is now used only for storage and the water from its gathering grounds is by-passed. The brochure gives statistical details of all of these reservoirs and of the various other works—trunk mains, tunnels, filtration works, service reservoirs, water towers, and pumping stations—owned by the undertaking. Owing to increases in consumption, various extension schemes were investigated after the war, but because of the need for avoiding heavy capital expenditure, the Ministry of Health requested the Corporation to ascertain if any expedients could be found to delay the construction of reservoirs as long as possible. A scheme for diverting additional streams into the existing system, to give an estimated increase of 3½ m.g.d. in the supply, was therefore put in hand and is due for completion next year; however, the first major work of the post-war period was the laying of a 48in diameter concrete-lined cast iron main from Swinsty reservoir to Eccup reservoir, which was started in 1948 and completed this year. A site for a new impounding reservoir in the Washburn valley has been investigated and geological investigations are proceeding. It is hoped that the construction of this reservoir, with a capacity of 1200 m.g., will be started soon and finished by 1962 at the latest. A filtration works with an initial capacity of 15 m.g.d. has also been planned at Eccup reservoir, which will incorporate a pumping station and allow an economy in pumping costs.

Fans in Agriculture

IN accordance with its usual custom, the Institution of British Agricultural Engineers held a meeting at Earls Court during the course of the Smithfield Show and Agricultural Machinery Exhibition. The meeting took place on Thursday afternoon of last week, and attracted a large company of members and visitors. The paper presented for discussion was by Mr. William Cover and Mr. Raymond C. Dick, and dealt with the use of fans in agriculture. It was pointed out in the paper that the application of fans to various aspects of farming was now well established, the duties ranging from the ventilation of buildings to the drying and storage of crops. The paper dealt with the characteristics of propeller, axial-flow and centrifugal fans, and made some mention of fan laws, resistance to air flow, and to several kinds of measuring instruments. Throughout the paper, the authors emphasised the importance of the selection and installation of fans for agricultural purposes, and stressed also the importance of proper maintenance. In agriculture, they said, the majority of fans were performing essential duties such as the drying or storage of crops, and breakdown could be more serious than merely irritating or inconvenient. A fan, they suggested, could be likened to the lungs of an air system and the fan motor to its heart. In the human body those organs must be in first-class condition and completely reliable. Regular maintenance of such important equipment was, therefore, obviously highly desirable.

The Melchett Medal

THE council of the Institute of Fuel has unanimously agreed to award the Melchett Medal for 1953 to Dr. Harold Hartley, C.B.E., in recognition of his high scientific attainments in the development of domestic heating appliances, coupled with the administrative skill with which he has guided a great industrial organisation devoted to the practical efficient use of fuel. Dr. Hartley is chairman of Radiation, Ltd. He is a native of the Isle of Man, and was educated there and at the Manchester Grammar School and Manchester University. He graduated head of his year in chemistry in 1907 and was elected to a Gartside Scholarship of Industry and Commerce, and after a year spent in the School of Economics at Manchester he visited Norway and Canada to study the production of power for electrochemical industries. On his return to England, he worked for three years as a Gas Research Fellow at Leeds University under the late Professor W. A. Bone. In 1912 Dr. Hartley was appointed chief chemist to the Richmonds Gas Stove and Meter Company, where he built up a technical and research section and continued the work on the measurement of the radiant efficiency of gas fires which had been started at Leeds in 1908. In 1919 he was awarded the degree of D.Sc. of Manchester University, and the same year he was appointed head of the research department of Radiation, Ltd. Dr. Hartley has directed many important investigations into the design of gas-fired appliances, including those culminating in the production of the Bennett/Hartley integrating radiometer for determining the radiant efficiency of domestic heating appliances. He was elected to the board of Radiation, Ltd., as technical director in 1938, became deputy chairman in 1948 and succeeded to the chairmanship in 1949. Besides serving as president of the Institution of Gas Engineers in 1947–48, Dr. Hartley has been chairman of the council of the British Cast Iron Research Association and, from 1945–47, president of that body. He is president of the Institute of Vitreous Enamellers, and is also one of the D.S.I.R. visitors to the British Coal Utilisation Research Association. He has been a member of the Institute of Fuel since 1944 and was elected a Fellow in 1948.

The Physics of Particle Size Analysis

THE Institute of Physics has announced this week that it is arranging a conference on "The Physics of Particle Size Analysis," which will be held at the University of Nottingham from April 6 to 9, 1954. It is now about five years ago that the last British conference on particle size analysis took place. It is anticipated that the various sessions of the 1954 conference will cover not only such fundamental physical processes as the fluid dynamics and the optics of particles and systems of particles, but also accounts of other phenomena encountered in particle size analysis such as the aggregation and dispersion of particles in a fluid. Arrangements are to be made also for a discussion on "automatised" methods of counting and sizing. It is stated that although the conference will be concerned primarily with the physical principles of particle size analysis, the development of new instruments and their uses will receive attention, particular interest being attached to the systematic comparison of different methods of particle size analysis. The organising committee is prepared to consider offers of papers, describing original work, for reading and discussion at the conference. A synopsis of any proposed contribution should be sent, before February 3, 1953, to the honorary secretary of the conference, Mr. R. L. Brown, Institute of Physics, 47, Belgrave Square, London, S.W.1. The complete manuscripts of accepted papers will be required by the end of October, 1953.

Atomic Explosion Film

A PART of the official film record of the explosion of Britain's first atomic weapon, was released to newsreels and television organisations for public showing throughout the world on Thursday of last week. The film opens by showing the Monte Bello Islands, off the North-West Coast of Australia, and the squadron of ships engaged in the test, which was carried out in conjunction with the Australian Government. It gives an indication of the preparatory work, by British and Commonwealth Forces, in constructing roads and landing piers, preparing beach heads and building laboratories and living accommodation. One important aspect of the test was to obtain information to aid Civil Defence authorities to design structures to withstand atomic blasts, and the film shows an Anderson shelter which was subjected to the blast and some specially designed concrete block structures built at chosen distances from the centre of the explosion. Before the explosion the film switches to the assembled crew of H.M.S. "Plym," turned away from the explosion. In the distance, behind them, a towering column has developed before they turn round. The top cloud surges upwards because it is a little hotter than the air around it until—at a height of about 2½ miles—it ceases to rise. Then, with radio-active rain falling from the cloud, the strong differential winds tear the immense column into a ragged shape. Finally, the great cloud is drawn by winds into a large Z which sprawls across the sky.

Hatfield Technical College

ON Monday last, December 15th, the new Hatfield Technical College was officially opened by the Duke of Edinburgh. The college is at present organised in five departments—engineering, technical and design; engineering, works and production; building; commerce and retail trades; and social and professional studies. The technical and design engineering department is arranged to provide instruction to a high level in the main branches of mechanical, aeronautical and electrical engineering. As this department develops in the next few years the scope of the courses will be widened considerably and it is envisaged that full-time courses leading to the award of external university degrees will be offered in selected subjects. At present this department has a well-equipped aerodynamics laboratory, an aircraft structures and materials laboratory, an aircraft ground engineering laboratory, a heat engines and a temporary hydraulics laboratory, a materials and metallurgy laboratory, a general science laboratory, and electrical engineering laboratories. These laboratories will be used in conjunction with those of the works and production engineering department, when necessary. This works and production engineering section provides full and part-time courses in production engineering, machine shop engineering, metal plate work, electric arc and oxy-acetylene welding, motor trade and agricultural engineering, electrical installation, heating and ventilating, and foremanship. It has a number of well-equipped workshops and laboratories, and the courses are designed to prepare candidates for the National Certificate examinations in mechanical and production engineering and examinations of the City and Guilds of London Institute.

Trans-Canadian and British Railway Experiences

By EDWARD H. LIVESAY

No. VI—"THE CAPITALS LIMITED"

(*Concluded from page 785, December 12th*)

The author has made a number of recent journeys on Canadian and British Railways and his reminiscences of these trips are set out in this series of articles. They began with a comparison of the two transcontinental railways—Canadian National and Canadian Pacific—giving an account of a journey from Victoria to Vancouver via Nanaimo, C.P.R., and another from Vancouver to Montreal on the C.N.R. Here he extends the comparison to "The Capitals Limited," British Railways.

LAST week's article was written late in 1951, and from the tone of it the reader will gather that I was somewhat disappointed with what transpired, particularly in the condition of the engine, which was poor—things had certainly been different in 1939. So I was glad to hear from Mr. Simpson, the Superintendent at King's Cross Locomotive Depot, when visiting his sphere of influence in June, 1952, that they were altogether better now, and he suggested that I make the run again and note the improvements that had been brought about during the preceding winter; he could practically guarantee a good run this time. At King's Cross they had got back to the "two-crews-one-engine" pre-war arrangement, with the result that the men took a real interest in their engines; many "A4s" were in good condition again; numerous speed restrictions had been removed due to work done on the track; and, lastly, the schedule of "The Capitals Ltd." had been cut to 7 h 6 min, only 6 min more than the "Flying Scotsman's" timing in 1939. Yes, I really ought to do the run again, note all this and add a sequel to the account written six months before, in justice to everyone concerned. The suggestion appealed to me, so, in due course, a return trip on "The Capitals Ltd." was arranged, thanks to the kindness of the Railway Executive. The engine was to have been "Sir Nigel Gresley," but No. 60033, "Seagull," a King's Cross "A4" backed on to the train on the chosen morning; "Sir Nigel Gresley's" middle big-end, the Achilles heel of three-cylinder engines, had been found slightly defective, not good enough for this 392 mile non-stop run. I had asked that Inspector Hart might accompany me again, promising to look after him better, and on this condition my request was granted; I was to see he didn't get his foot caught this time. "Seagull" certainly looked very well; it brought back nostalgic memories of 1939 and "Commonwealth of Australia" and of the days when engines not only looked nice but *were* nice. "The Capitals Ltd." pulled out at 9.38, 3 min late, an engine returning to the shed having been allowed to foul our track; a poor piece of staff work, and scarcely a good omen. However, everything else was propitious: enginemen Dines and Spilsbury were in charge, with Hart standing by; steam was near popping-off point, regulator three-quarters, cut-off 35 per cent, and steam chest pressure 220 lb. The load was eleven coaches, say, 400 tons, and there was no slipping.

All the way up the long 12¾ mile climb out of London the regulator remained at three-quarters, but the cut-off was progressively reduced until it was only 17 per cent as we passed Potters Bar, the top, at 50 m.p.h. "Seagull" was riding well and there were no knocking axleboxes this time: there was no Flaman indicator either.

Immediately after topping the bank ill-luck struck: first a relaying slack brought "The Capitals Ltd." down to 20 between Brookmans Park and Hatfield, and in the station it was halted for 15 sec and given orders from the signalbox to proceed cautiously thereafter to Welwyn Garden City, so the non-stop feature of the schedule had been spoilt right at the beginning of the run. The "London 20 miles" board passed at 10.10—32 min from King's Cross—nothing very encouraging about that! Then over Welwyn Viaduct; there is no actual speed restriction here, I believe—or is it 70?—but two "Pacifics" must not cross it coupled together.

Down from Stevenage the speed had risen to 80—through Hitchin it was 85, with the regulator less than half open and cut-off 15 per cent; at Sandy this was 12 per cent, the lowest I noticed during the run. The riding was again noted as good at this figure, much better than "Kingfisher's" had been, and we continued at this encouraging velocity through Three Counties until the engine was eased at Arlesey; a long straight here, a good racing stretch. Biggleswade 10.30, 41½ miles in 52 min, with the last 12 miles in 9½—"Seagull" must really soon begin to show better wings than this, I thought, or we shall be for ever undone. Huntingdon was passed 6½ min late; Peterborough—restricted to 20—at 11 a.m.; 76 miles in 82 min—things were improving. Leaving the water-trough just north of Peterborough, "Seagull" blew off for the first time; Spilsbury was credited with being "a good man—steam always well up"—incidentally there was a Kylchap double blast-pipe fitted. She was reported as being a good steamer; had been used in the 1948 Exchange trials, and had probably run over 750,000 miles.

Grantham, 4½ min late; Retford, 12 noon, only 1 min. At Doncaster, 12.19½, we were 2 min ahead of time, after which we ambled at 60/65 along fine, tempting straights through country flat as a pancake, the Naburn swing-bridge bringing us down to 40. Then slow through York, 12.54, 1 min early, and the people in the cab began to think of dinner, and the "change of watch"; this took place at Skelton, three of us adjourning to the dining-car, leaving Hart, conscientious man, prosecuting his vocation in the cab. This being so, it is only natural that nothing whatever appears in my note-book until Chevington, a hundred or so miles farther on, was reached—evidently both the lunch and the company must have been satisfactory. During this gastronomic interlude, Northallerton had been passed at 1.23, 1 min early—Darlington, 4 min late—and Durham and Newcastle both 7 min late; I regret being unable to state why, as nothing had been put in my note-book, only into my stomach. Hart's log sheds some light on things, however: "Darlington, 5 min lost—signals and turned platform line, 15 m.p.h."; near Durham, "4 min lost—P-way caution." On getting back to the cab again I punctiliously took to my note-book as we flashed past Chevington, 294 miles from London; the weather, previously dull, was lovely now, and "a certain liveliness" was evident on the engine's part, 75/80 being clocked shortly after, with "Seagull" blowing off, this indication of superabundant energy having been demonstrated more often than on previous non-stop runs. "Seagull" was clearly a good steamer and Strachan, the Scottish fireman, another good man. I was beginning to think well of Driver Barlow, too, now that I could watch his work at close quarters: there seemed to be a lot of sustained fast running north of Newcastle, making it look as though he were trying to recover those 7 errant minutes. The sea, sighted near Alnmouth, was of almost Mediterranean blue, and everything inside and outside the cab was pleasing, Berwick, 335 miles in 353 min, average 57, was passed at 3.31, only 1 min late—much better—in fact, O.K.

Just across the Border—nice to be in Scotland again after the long winter's absence—there was a strict, not-to-be-scamped restriction of 5 m.p.h. over a bridge under reconstruction at Burnmouth, which was conscientiously obeyed—at any rate we must have come down pretty near it! For some time there had been a good deal of climbing, high-lighted by the Cockburnspath bank, at the top of which "Seagull" was going very strong, only 1½ min late. I began to wonder if "The Capitals Ltd." was going to fulfil my desire, openly voiced in London, that those miserable 6 min might be eliminated from the booked time, and the pre-war 7 h flat of the "Flying Scotsman" equalled. Everyone concerned had been hopeful but would not commit themselves—they would see about it, but success depended on many factors that could neither be foreseen nor controlled—traffic, signals, weather and so on—even, peradventure, the middle big-end! We would have to wait and see.

Dunbar, with the Bass Rock looming grimly ahead—I think it is Bass Rock—coincided with a heavy shower, but running into Edinburgh it cleared and both weather and observer became more cheerful. It had been an interesting trip, more pleasant than the year before; there had been no complaining axlebox thudding dully all the way; a late start, a dead stand at Hatfield, considerable time lost and regained, until now we were ahead of schedule. Could "Seagull" eliminate those 6 min—was it allowable? Apparently it was, and "Seagull" could, according to my notebook, as "The Capitals Ltd." came to a stand in Waverley Station at 4.35 p.m., 6 min ahead of schedule. Hart's log confirms this statement, so let nobody contradict it. The clock had been set back to 1939; 392 miles had been covered in 417 min, at an average of 56·1 m.p.h.

Certainly the run had been better than that of "Kingfisher" the year before. Inspector Hart's log is much pleasanter reading: "Delays: signals 10, P.-way 13, stations 3, engine 2½—gains: recovery time 9, engine 25½. Remarks: driving and firing work by both crews very good. Engine condition good. Steaming good. P.-way speed restrictions observed." And so say both of us.

This matter of the strict observance of restrictions came on the tapis in Glasgow a day or two later. I had gleefully mentioned to an official that we had arrived in Edin-

burgh 6 min ahead of schedule. "Aye, I know ye did!" he said, somewhat sternly; "but *did ye obsairve the 5 m.p.h. restriction ower the bridge at Burrnemouth?*" "*Yes!*" I retorted, in the most emphatic Anglo-Saxon; "we *did*!" He looked at me quizzically over the top of his spectacles, apparently not quite convinced even then—as if I had anything to do with it!—adding, with a sigh, "Well, I hope ye did!" So once again, and for the last time, I categorically assert, "We *did*!" (Or, at any rate, we must have got very near it—a little bit less and we should have stopped altogether!). All the other restrictions were observed, too, as closely as possible—that is to say, as closely as the absence of any sort of speed-recorder would allow. How *can* a driver be expected to exactly hit off a succession of speed restrictions of widely differing degree without the assistance of a proper indicator? In France, now, every engine of every kind, steam, electric, diesel, autorail, heading trains also of every sort, express, local, push-and-pull, freight—they *all* have the Flaman or Hasler recorder. In my humble opinion every express engine, at any rate, should be equipped with one; the "A4s" were so fitted before the war, even though the device was an afterthought, and had to be stowed away under the fireman's seat.

So much for the "down" run—a few notes now on the "up". The engine was another "A4," No. 60027, "Merlin," a Haymarket machine; the crew were Messrs. W. McLeod and G. Drummond, with Inspector Cunningham holding a watching brief.

"The Capitals Ltd." left Waverley Station at 9.50 a.m., 5 min later, due to the tardy arrival of a connecting train from Aberdeen. As before, the load was eleven coaches, 400 tons, and with natural anxiety to get away smartly, a very snappy start was made and full advantage taken of the 1 in 98 drop immediately outside, but this initial exuberance was promptly checked by a restriction to 20 between Newhailes and Inveresk. These restrictions—it still seems difficult for an observer to grasp their necessity; the track *looks* so good he is apt to wonder why the restrictions are imposed at all. Recovering from this check, the speed soon reached 75, at which the riding was noted as "Good—condition of engine also good"—no knocks, clanks or wheezes anywhere. Up the steep Cockburnspath bank the speed held at about 45 until near the summit, where it had fallen to 35/40. There was no Flaman on this engine either; this invaluable speed-recorder and indicator now seems but a memory in Britain.

At the Granthouse summit, 10.34, we were 2½ min later, and the 5 m.p.h. restriction over Bridge 154 at Burnmouth was meticulously observed—more or less!—and we were only one minute late at Berwick, while at Belford, a few miles farther on, "The Capitals Ltd." was dead on time. The "London 300 miles" board was passed at 11.27, so the 92 miles from Edinburgh had been covered in 97 min. At Newcastle we were 3 min early and at Durham still slightly so, and everyone was happy and hopeful at our satisfactory progress until at Parkgate signal box, just outside Darlington, the whole non-stop schedule went to pieces. "The Capitals Ltd." was halted for no less than 8 min; it seemed we had been treading on the tail of the 11.55 from Newcastle ever since passing that city, and, finally, it was decided this was to be taken out of our way, but as luck would have it, the 11.55 was itself hampered by Saturday afternoon summer traffic, and it was 12.56 before the "Capitals" was finally allowed to proceed, 15 min behind schedule. The stars in their courses seemed fighting against us; at York we were still 14 min late, though the preceding 28 miles had been covered at 74 m.p.h. The "change of watch" took place at Skelton, as before, Enginemen Springham and Baxter taking over for the rest of the run to London. Speed was high south of York and the riding somewhat turbulent, with considerable rolling; evidently due to the track. Nearing Newark we were certainly doing 80, and steadily regaining the lost minutes, when hopes were again dashed by the train being brought to a dead stand nearing Peterborough—Saturday afternoon traffic. Away once more, another determined effort was made to get back on to schedule by sustained fast running. South of Huntingdon, only 3 min late, Baxter shouted: "We are coming to the Offord curves—you'd better hold on—we shall be doing some rolling!" Well, as a sailor, I like a little rolling; it is fast, angry jerking and nosing, coupled with oscillation and vibration I object to, and I quite enjoyed the easy, steamer-like swaying indulged in by "Merlin" on the said Offord curvature—it was somewhat like a destroyer steaming fast in a beam sea. At Potters Bar we were 6 min behind time, and then checked by signal, so it was no surprise, though disappointing, to come to a stand in King's Cross 3 min late. "Merlin" had made a good run, though hampered from beginning to end by outside influences, and my record was borne out by Inspector Cunningham's log, which reported: "34 min lost and 31 regained." The 392 miles had been covered in 414 min running time, at an average speed of 56·3 m.p.h.

The run typified conditions on main lines of British Railways as they are at present. Things *are* getting better; I have noticed it myself on many occasions, but still pre-war schedules cannot be quite equalled, chiefly due to the track not yet having been brought back to what it was before the tragedy of 1939; traffic is heavier than ever, too, which brings signal delays. Incidentally, this was a Saturday trip and so far as trackworkers were concerned, the line was deserted from Edinburgh to London—not a man was to be seen anywhere. A five-day week, of course—but can we afford it? The following week I was in France, and saw plenty of work going on along the track there on Saturdays, though, to be frank, the men did not seem to be exactly killing themselves on the job!

A final word in justice to the staff at King's Cross shed. The "A4s" *are* in better condition, if "Seagull" is fairly representative—the "two-crews-one-engine" plan seems to be working well—the schedule had been cut—the track was in better condition. Let Haymarket get a pat on the back, too—there was not much the matter with "Merlin" either. It was a pleasure to travel on both engines; I could not be quite as complimentary to "Kingfisher" last year. But I do wish the Flaman recorders had not been removed—the runs would have been more enjoyable with their assistance, to me at any rate.

In the first article in this series (Nov. 14, 1952, page 639) reference was made to the "26 mile crossing" from Nanaimo to Vancouver. We should point out that the distance by steamer is 46, not 26, miles.

Locomotive No. 5704 illustrated in Fig. 15, page 746 belongs to Canadian National Railways, not C.P.R. as stated in our caption.

Aluminium as a Cable Sheathing Material

By D. McALLISTER

No. I

Now that aluminium sheaths have become firmly established for most types of cable, it is possible to form a balanced picture of their advantages and limitations. For coaxial telecommunications cables, the sheath is an integral part of the cable, but, in the general case, with insulation of paper, rubber, plastics or varnished cambric, aluminium is an alternative to lead and its use does not affect the basic design of the cable. This article gives details of the new techniques which have been developed for sheathing and handling the cables, together with an account of the general properties of aluminium sheaths.

UNTIL shortly after World War II, when a period of lead shortage provided the incentive for the development of aluminium sheaths, no other metal had been able to compete with lead for cable sheathing. The technical advantages of aluminium, together with its economic advantage at the metal price levels of recent years, have subsequently enabled it to become established not as a substitute for lead, but as an attractive alternative. Extensive field trials have been carried out and several thousand miles of cable are already in service.

Advantages and Disadvantages of Aluminium

The advantages of aluminium are primarily that it is considerably lighter and stronger than lead. A large proportion of the weight of a lead sheathed cable is in the sheath and the reduction with aluminium is remarkable. In the case of power cables, the saving in weight varies from about 60 per cent for small cables to 30 per cent for large cables, with an average of about 35 per cent for unarmoured and 25 per cent for armoured cables.

Another disadvantage of lead is its softness and lack of mechanical strength. Thus a bare sheath is easily scored if not handled carefully during installation, and additional protection and mechanical strength have often to be provided by steel tapes or galvanised steel wire armour, both of which have to be well protected with servings if they are required to last for the life of the cable. Except in special circumstances, armour is not necessary with aluminium, and this is another factor in further reducing weight and cost. Nowadays, it has become necessary to carry more power underground at very high voltages, and it is usual to use oil-filled cables or cables operating with a high gas pressure, generally of 200 lb per square inch. In both cases reinforcement of the lead sheath is required and the provision of steel or copper alloy reinforcement tapes and their protection against corrosion

becomes quite elaborate ; aluminium sheaths can withstand such pressures satisfactorily without any reinforcement.

A further disadvantage of lead, which is well known to most cable users, is its liability to fracture by vibration. Because of the characteristic appearance of this type of fracture, it is often referred to, quite erroneously, as failure by crystallisation of the sheath. Actually, all metals have a crystalline structure and this fatigue failure is brought about by fine cracks spreading through the crystal boundaries. In this respect aluminium is several times stronger than the best lead alloys and failure is not likely to occur, even when cables are installed in positions of severe vibration.

As will be discussed later, the additional stiffness of aluminium has both advantages and disadvantages. For installations in which there is plenty of room to work, it makes handling surprisingly easier. However, when conditions are difficult, and there are frequent bends of small radii, the greater flexibility of lead is a point in its favour. The stiffness of aluminium has, therefore, to be considered, and allowance made for the fact that, especially with large cables, it is desirable to use somewhat larger bending radii. For forming small radii bends when fixing cables into their final position for cleating, the use of special tools may be desirable.

Another point in favour of lead is the ease with which it can be cut and plumbed. Plumbing can be carried out quite satisfactorily on aluminium, but it takes longer and requires more care.

Finally, there is the question of corrosion. Although the available information is limited, it seems prudent to employ a completely impermeable serving for aluminium sheathed cables which are to be buried in the ground or in ducts. Aluminium is resistant to many conditions, but it appears to be susceptible to certain forms of attack which can occur underground.

Production of Aluminium

We have now become much more conscious of the sources of supply of our raw materials and are especially interested in whether dollars are involved. The amount of aluminium produced in the U.K. is quite small. In recent years it has been fairly steady at about 30,000 tons per annum, whereas imports—mostly from Canada and requiring dollars—have been around 150,000 to 175,000 tons per annum. Lead now comes mainly from non-dollar sources.

Canada's position as a producer of aluminium is curious and interesting. She possesses none of the raw materials required and has to import about 7 tons of these to make 1 ton of aluminium. The economic advantage is in the cheap electric power available, the final stage in the manufacturing process being the electrolysis, at nearly 1000 deg. Cent., of aluminium oxide dissolved in molten salts. This requires about 10kWh per lb of aluminium and by developing hydro-electric generation, an industry has been built up such that 85 per cent of the 352,000 tons of aluminium produced in 1950 was exported. Looked at another way, it would take about 15 tons of coal to generate sufficient electricity for the production of 1 ton of aluminium.

The use of the electrolytic process enables a high purity product to be obtained from the oxide in one stage. All the aluminium used for sheathing is virgin metal produced in this way and is of a purity of 99·5–99·7 per cent. The chief impurities are silicon (0·1–0·2 per cent), iron (0·2–0·3 per cent), manganese (0·01 per cent), and copper (0·01–0·02 per cent). Although it is generally recognised that purity is of importance for cable sheaths, because the higher the purity the better the corrosion resistance, the actual effect of total purity in the economical range for sheaths is not very significant. It is only with super-purity metal containing 99·99 per cent aluminium that substantial improvement in corrosion resistance is obtained. This, however, is not yet available in adequate quantities for general use and in any case has to be ruled out at the present time because of the high price.

A suitable grade of tubing for cable sheathing is material T.1.B. in B.S. 1471, for which 99·5 per cent minimum purity is specified. Of the individual impurities, copper is the most undesirable, again because of corrosion resistance, and although in the above grade the limit is 0·05 per cent, the amount present is invariably considerably lower than this.

The Development of Aluminium Sheathing Processes

The first large-scale experimental work on the use of aluminium for cable sheaths was started in Germany just before the second World War, the incentive being to economise

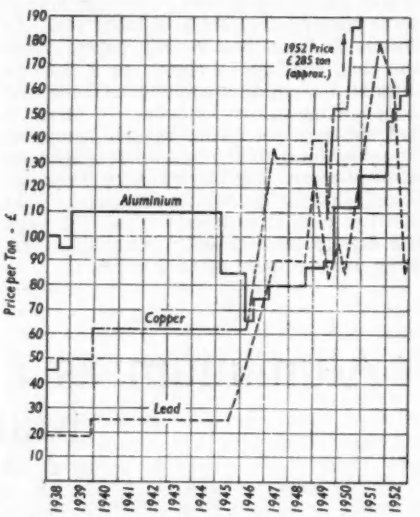

Fig. 1—Price Trends for Lead and Aluminium Ingots and Copper Wire Bars

in the use of lead, which, it was foreseen, would be in short supply. Two methods were tried : (*a*) folding a strip of aluminium sheet round the cable and resistance welding an upset longitudinal flange, and (*b*) direct extrusion. The former did not meet with much success, but considerable work was done on the extrusion method and, although a satisfactory process was not developed, it appears that a number of small diameter cables were sheathed and made available for commercial use.[1,2] The development of suitable extrusion presses was continued spasmodically during the war but the difficulties were not overcome.

In this country aluminium was not available during the war and, in any case, it was very expensive compared with lead. Conditions changed rapidly immediately after the war. Lead prices rose to unprecedented heights, whereas aluminium remained steady (Fig. 1), so that aluminium sheaths became an economic proposition. Moreover, aluminium was then abundant and lead was extremely scarce and severely rationed, so that to a large extent the volume of cable output was determined by the lead available.

Experiments were immediately put in hand by British cable makers. As some of the difficulties which had confronted the Germans in direct extrusion were known, this method was investigated but not given high priority. Attention was mainly directed to the use of welded sheaths formed from aluminium sheet and to the "died down" method. The latter has been proved to be a simple and satisfactory process and though it has some drawbacks, it is the only one which has been fully developed and put into commercial operation to any extent.[3]

The Died Down Sheathing Process

Plant Requirements.—The basic principles are quite simple, but a lot of space is needed and methods of handling required considerable development to provide an economic process. It is interesting to reflect that it is the original method adopted for lead sheathing towards the end of the last century.

The first requirement is to lay out and support in as near a straight line as possible, a sufficient length of tubing for the required length of cable. In modern cable practice 440 yard lengths are quite common and, for aluminium sheaths to be competitive, the runway must be of this length. At the Erith works of British Insulated Callender's Cables, Ltd., a 480 yard conveyor was obtained by building a special covered roller track from the end of the longest workshop available and extending this across a corner of the sports field. Even so, a bend of 100ft radius had to be included in the last 180 yards, experiments having shown that the friction and pulling tensions were not excessive for a bend of this large radius. The track comprises two sets of curved rollers at 5ft spacing, with additional vertical rollers at 3ft spacing round the bend. To avoid interfering with traffic inside and outside the shop the track is 12ft above the ground. According to the method adopted, handling facilities may be required at one or both ends. In the above installation all the operating plant is placed at one end and pulling hawsers pass round a large-diameter fixed pulley at the remote end.

The sinking die is at the indoor end of the conveyor and beyond this is a 12ft diameter capstan for pulling the cable through the die. To obtain good friction on the aluminium sheath this capstan has a wood bearing surface. Next to the capstan is a drum pit with driving gear coupled to the capstan through a slipping friction clutch. Finally, there is another drum stand which is not driven and is used for the tubing and cable core. This drum is at ground level and there is a curved roller chute to guide the cable and tubing to the height of the main conveyor.

The Process.—The method of operation can best be explained by reference to the sketches in Fig. 2. First, the tubing is drawn out from the drum to the conveyor, (*a*) (Fig. 2), being made circular and straightened at the same time by passage through a die to give a reduction in diameter of about 2–5 per cent. The power is obtained by having the drum of the hawser in the main driving position. An extension tube, of diameter equal to or greater than the tubing used for sheathing, is attached to the leading end. The reason for this is that initially the cable core is longer than the sheathing tube, which, however, increases in length as its diameter is reduced during dieing down ; the extension tube protects the excess length of core until the main tube has extended to cover it.

A light hawser is attached to a plug which has conical rubber discs to fit the tube and this plug assembly is then blown through by compressed air (*b*) (Fig. 2). At the remote end the light hawser is attached to the main hawser and a complete lead is

then available for pulling the cable into the tube (*c*) (Fig. 2). The inner ends of the tube and the cable conductor inside it are now connected together by special accessories, the end of the tube swaged down to give a smaller diameter to permit entry into the main sinking die (*d*) (Fig. 2), and the whole length is pulled through the die to reduce the diameter of the tubing to fit the core (*e*) (Fig. 2). The pull is obtained by passing the sheathed cable round the capstan and from there it is taken to the coiling-on drum, the drive for which is linked with the capstan. The main hawser is still attached to the trailing end of the

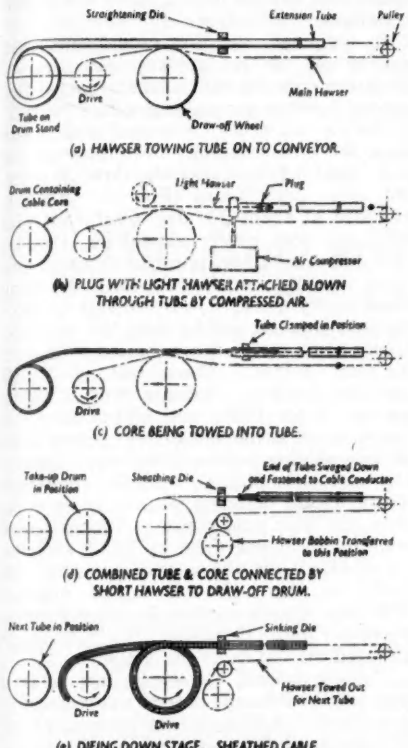
Straightening Die
Extension Tube
Pulley
Drive
Main Hawser
Tube on Drum Stand
Draw-off Wheel
(a) HAWSER TOWING TUBE ON TO CONVEYOR.
Drum Containing Cable Core
Light Hawser
Plug
Air Compressor
(b) PLUG WITH LIGHT HAWSER ATTACHED BLOWN THROUGH TUBE BY COMPRESSED AIR.
Tube Clamped in Position
Drive
(c) CORE BEING TOWED INTO TUBE.
Take-up Drum in Position
Sheathing Die
End of Tube Swaged Down and Fastened to Cable Conductor
Hawser Bobbin Transferred to this Position
(d) COMBINED TUBE & CORE CONNECTED BY SHORT HAWSER TO DRAW-OFF DRUM.
Next Tube in Position
Sinking Die
Hawser Towed Out for Next Tube
Drive
Drive
(e) DIEING DOWN STAGE. SHEATHED CABLE WOUND ON TAKE-UP DRUM.

Fig. 2—The Dieing Down Method of Sheathing

cable, so that at the completion of sheathing it is available for pulling out the next length of tubing.

The above account gives only the essentials of the process and a number of modifications may be adopted to obtain accelerated working ; for instance, one long length of tubing may be used for several short cables instead of laying out a separate length for each.

Sizes of Tubing.—Sheath thicknesses are discussed later and it is sufficient to note here that it is necessary to have as many as sixteen standard sizes of tubing to cover normal cable requirements. (Table I).

TABLE I.—*Standard Aluminium Tube Sizes for Cable Sheathing*

External diameter, inches	Mean wall thickness, inches
0·375	0·035
0·5	0·035
0·625	0·035
0·75	0·04
0·875	0·045
1·0	0·05
1·25	0·055
1·5	0·065
1·75	0·075
2·0	0·085
2·25	0·095
2·5	0·105
2·75	0·115
3·0	0·125
3·25	0·135

When first considering the dieing down process of sheathing, it was obvious that, to keep the required stock of tubing within limits, the number of individual tube sizes must be as few as possible. In dieing down, the wall thickness of the tube remains substantially constant, actually it increases a little, but apart from preventing this increase it is quite difficult to alter it, so that for every step of sheath thickness required one or more diameters of tubing are needed of that thickness.

Having determined the sheath thicknesses necessary, the next stage was to decide on suitable internal diameters of tubing, a sufficient clearance for pulling in the cable being allowed for the largest cable in each step of wall thickness, and the external diameters were then conveniently rounded off to $\frac{1}{8}$in or $\frac{1}{4}$in sizes. There is, however, a limit to the amount by which aluminium tubing can be conveniently reduced in diameter by dieing down and, for small sizes, this limit is about 40–45 per cent. It was found that if thickness steps of 10 mils were adopted, as for lead sheaths, greater reductions than the above were necessary in the ranges up to 0·05in thickness and it was judged to be better to have 5 mil steps of thickness at the lower end instead of having two different diameters of tubing for each 10 mil step. This is the reason for the departure from lead practice.

Characteristics of the Tubing.—The production of long lengths of tubing by aluminium suppliers was a new venture which they tackled energetically and successfully. The nearest approach to this kind of work had been conduit and scaffolding, both of which are required only in short lengths, in which any defects can be cut out during manufacture. Moreover, such faults as tiny pinholes, which would cause little harm in conduit, for instance, would be disastrous in the sheath of a paper insulated cable.

Experience showed that each length of tubing had to be extruded from a single billet as, when successive billets were fed into the press, defects such as blisters due to entrapped air between the billets were obtained in the tubing extruded from the metal in the region of the billet joints. Furthermore, the stop marks formed at the die on any stoppage of the press had a deleterious effect on the bending properties of the sheath, as kinks tended to form on them. The need to use single billets imposes a restriction on the lengths of large diameter cables which can be sheathed. Although some of the aluminium presses in this country are of 6000 tons capacity and can handle billets up to 20in diameter and 700 lb weight, the longest length of 30in diameter cable which can be sheathed is of the order of 160 yards. Also, tubing suppliers do not find it convenient and economic to use these large presses for relatively small quantities of tubing. To ensure good concentricity, the dies are of the port-hole type and[4] hollow (pierced) billets are not used.

As hardening occurs during dieing down, the original tube should be as soft as possible and it is, therefore, obtained in the "as-extruded" condition, which, as the extrusion temperature is high, is more or less equivalent to the "annealed" state. An exception is that for very small tubing it is sometimes more convenient for the supplier to extrude a larger size, then draw down, degrease, and finally anneal.

It is not a difficult matter for the cable maker to institute a reliable inspection procedure and, in addition to visual examination for blisters, scores and similar defects, every length of tubing is tested under gas pressure to ensure freedom from faults of the pinhole kind. If the tubing is for use on cables which normally operate under internal pressure, such as impregnated pressure cables, the test is at the cable operating pressure of 200 lb per square inch. In all cases, the test is made very sensitive by shutting the tubing in under pressure and checking that no fall of pressure occurs over several hours. Periodic special tests, such as the examination of polished and etched cross sections and pressure tests to destruction, are also carried out.

As it is used in the as-extruded state, or after annealing, the surface of the tubing is perfectly clean and there is no fear of any contamination of the cable. Care is taken to prevent sawings at cut ends from accumulating inside and a cloth pad is pulled through in front of the cable to trap any stray particles. Moisture is excluded by ensuring that all lengths of tubing are sealed during transit and storage.

Characteristics of the Process.—"Dieing down" sounds cumbersome, but has the merit of being expressive. The process cannot be termed "drawing," because this generally denotes reduction of both diameter and wall thickness. When the wall thickness is maintained constant the operation is commonly called a "sinking" process.

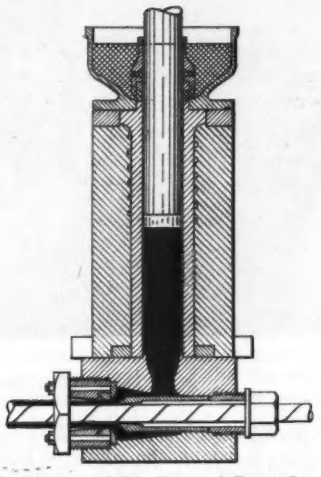

Fig. 3—Diagram of Die Box and Press Container with Glover Tray for Lead Sheathing

The relation between the initial diameter and length of the tube (d_1, l_1) and the final dimensions (d_2, l_2) is given by $l_2 = d_1 l_1 / d_2$ so that if 200 yards of 1·0in diameter tubing are reduced to 0·75in diameter the length idcreases to 266 yards assuming the wall thickness to remain constant.

In practice, however, the wall thickness increases very slightly, especially with large reductions, and it is desirable to use special die shapes to keep the increase to a minimum. In essence, the die merely consists of a tapered hole in a thick steel plate. Normally, the sinks are kept as small as possible, usually in the range of 10 to 30 per cent reduction of diameter. For high reductions the dieing down has to be carried out in two stages, otherwise the pulling tension might be sufficiently high to cause thinning or fracture of the tubing.

Satisfactory lubrication at the die is very important, because aluminium will readily adhere to a dry die face and when this happens the sheath becomes badly scored throughout the remainder of the length. A novelty in the B.I.C.C. process is the use of a solution of bitumen at the straightening die and hot bitumen at the final die. Apart from giving good lubrication, this method ensures that the bitumen is well keyed to the surface of the aluminium and provides a very uniform protective layer against corrosion. If oils or greases are used, it is necessary to have a degreasing bath to remove them prior to the application of protective coatings on the aluminium ; the use of bitumen avoids this.

No difficulty has been experienced in sheathing cables with any normal type of insulation. In a lapped construction the outer tapes should be interlocked ; the outer copper woven fabric tape commonly used as a binder for high-voltage multi-core cables gives a satisfactory outer layer suitable for both impregnated and unimpregnated cables. Reference has already been made to the exclusion of moisture during storage of the tubing and to the protection of the protruding length of core during sheathing. Even if the conveyor is in the open no moisture can enter the sheath. As a further precaution, however, the whole of the conveyor is covered over. After completion of manufacture and testing, the cables are again sealed by a lead cap plumbed on as for lead sheaths.

Providing the conveyor is straight, or rollers are correctly spaced in curved portions, the pulling loads both for drawing in the cable and for dieing down are quite low—of the order of a few hundredweights—and with well-designed plant there is no danger of the cable being damaged.

Limitations of the Died Down Process.—The process has the main advantage of technical simplicity and comparatively inexpensive plant requirements. It has, however, its limitations and disadvantages. For instance, a large stock of aluminium tubing has to be maintained and this takes up a lot of space—very much more than is required for ingots with a direct extrusion process. Furthermore, although not much working space at ground level is needed, there is the difficulty of finding room for a long conveyor more or less in a straight line. Another important factor is the length of tubing which can be obtained from single billet extrusions. Even when the very large presses can be used for the tubing the maximum cable lengths are of the order of 440 yards up to 1½in O.D. of sheath, 350 yards from 1½in to 2in, 300 yards from 2in to 2½in, and 220 yards from 2½in to 2½in O.D.

Another aspect is that whilst the hardness and stiffness of the cold worked sheath can be useful in some installations, the general case is that soft aluminium would be an improvement. Annealing is not practicable after sheathing, because the temperature required would damage the insulation of most cables and the only way the hardness and resultant stiffness could be reduced would be to use super-purity metal. This, however, is expensive and not yet available in adequate quantity. The use of any of the aluminium alloys so far developed would not give any improvement in this respect.

For these reasons, therefore, other methods of sheathing have been explored and development work is still continuing.

Welded Seam in Sheath from Strip

In this method of aluminium sheathing the basic principle is the folding of strip round the cable and joining the longitudinal seam by welding. The operation is rather an intricate one involving great accuracy in forming the edges together and in the welding itself, but some success has been achieved. In fact, the resistance welding of an upset fin was one of the first methods employed in Germany,[1] and the difficulty appears to have been more with the bending properties of the cable than the method of production. Attempts were made to effect an improvement by corrugating the sheath, but this was not successful and it would seem that the main effort was diverted to extrusion methods very largely because of the unsatisfactory bending properties. Also, although a large part of the fin can be machined off after welding, the remaining piece, even if folded over, is detrimental to the preservation of a good protective serving of lapped tapes.

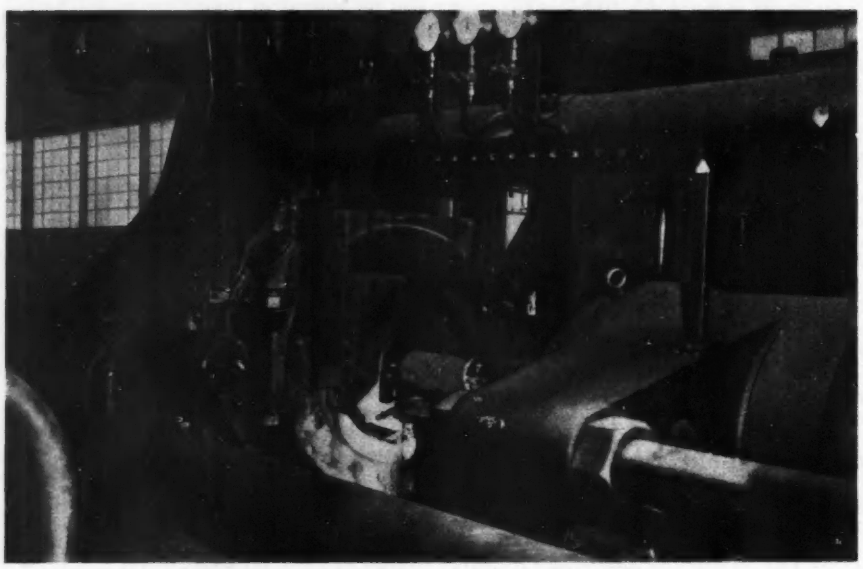

Fig. 4—Billet Entering Container of 1500-ton Press

The sheathing method from strip nevertheless has its advantages. The plant required is not unduly elaborate, no long runway is needed as for dieing down, it would be possible to sheath longer lengths of cable, and less storage space is needed for strip than for tubing.

Investigations have, therefore, been continued in this country and an account has been given of a more simple welding procedure.[5] In this process, the two surfaces of the fin are " pressure welded " by compression without heating. This is a very satisfactory means of welding aluminium, but there are still the drawbacks of the geometry of the arrangement. A further method under consideration is the formation of a butt weld to overcome the disadvantages of the fin, the weld being made by the electric arc process in an atmosphere of argon.

On the whole, therefore, it can be stated that although welding methods are being studied and some measure of success has been achieved, it may be some time before a fully satisfactory process is developed.

Extrusion

This method is universally adopted for lead sheaths and, apart from the high initial cost of the plant it has many advantages, of which the most important is its adaptability. With suitable dies, any diameter of sheath and any wall thickness can be obtained from billets which are easy to keep in stock. Also, because a high temperature would probably be unavoidable, extruded aluminium sheaths would be in the softest condition.

In Germany, the first experiments were carried out on an ordinary lead press of 2000 tons capacity with a vertical ram. This process involves a right-angled feed of metal to the die and welds are formed as the metal from the press container flows into the die box round a hollow male die through which the cable core passes (Fig. 3). Lead is extruded at about 220 deg. Cent., but with 99·5 per cent purity aluminium, even at 360 deg. Cent., the pressure required was three times that required for lead. By using super-purity metal, it was reduced to twice the lead pressure, and by using low extrusion speeds some success was achieved with small diameter cables. There was a further difficulty, however. Because of oxide on the surface of the billets and entrapped air at the junction, it was not easy to obtain satisfactory welding between successive billets in any extrusion process, and in the experiments, sheath defects appeared in the metal from the billet weld region. Attempts were made to overcome them by filling the container with liquid aluminium, as is done with lead, but the high temperature required (750 deg. Cent.) resulted in thermal stress troubles, and, moreover, the aluminium attacked the surface of the container.

The above work had shown that, at least with single billets, the process was reasonably practicable. Although lead presses are not strong enough for routine use on aluminium, quite a good deal of experimental telephone cable was manufactured for use by the German Post Office. Apart from some development work on the design of a horizontal press on the lines commonly used for the commercial extrusion of sections and tubing in copper and aluminium, the whole question of aluminium sheathing was then apparently abandoned. Incidentally, the reason why the extrusion presses used to make tubing cannot be used for sheathing, might be noted here. These presses operate in a horizontal straight line, and there is no facility for introducing the cable through the solid ram and the solid billet of metal in the press container.

In Fig. 4 a billet can be seen entering the container of a 1500-ton Loewy extrusion press of the kind used for the production of aluminium tubing.

Thus, although it is clear that extrusion has many advantages, the difficulties are formidable. First, there is the high temperature required and its effect on the cable insulation. At normal extrusion speeds there is no deterioration of dry or impregnated paper, but damage can occur when the press is stopped, so that unless steps are taken, such as the use of an effective heat-resistant tape on the outside of the cable core, the time for insertion of a fresh billet must be measured in seconds rather than minutes. An alternative method which has been the subject of several patents[6] is to extrude an oversize sheath and then reduce this, by dieing down, to fit the cable.

The avoidance of defects due to billet junctions is another major problem. The chief source of faults in this respect is probably the trapping of air between the two billets. Another is the concentration of impurities from the surface of the billet which occurs at the end of the billet, because of the nature of the extrusion flow. In conventional extrusion practice only about 80 per cent of the billet is used and a " discard " portion is taken out. For continuous extrusion it is desirable to use the whole length of billet. To obtain a smooth surface and dimensional stability at stop marks, is also a difficult matter.

There is also the high cost of the design work, manufacture and development of large extrusion presses. Except for very small cables up to, say, ½in to 1in O.D., lead presses are basically unsuitable for adaptation, as they were designed for operation at lower temperatures and pressures. A choice of two basic presses is possible, (*a*) a right-angled feed round the cable, and (*b*) a straight line arrangement with the cable fed through the ram. Both cases involve a completely new design of expensive extrusion press.

The position at the moment is, therefore, that except possibly for small diameter cables for which existing presses might be adapted, it is likely to be some time before extruded aluminium sheaths are available.

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6 British Patents Nos. 649,708; 644, 690; 631,127.

(*To be continued*)

The Iron and Steel Institute

AUTUMN GENERAL MEETING

No. III—(*Concluded from page 787, December 12th*)

THE final session of the autumn meeting, in London, of the Iron and Steel Institute was held on Thursday morning, November 27th, with the president, Captain H. Leighton Davies, in the chair. The first paper to be discussed was :—

ADDITION OF BORON TO STEEL BY REDUCTION FROM BORON OXIDE

By G. E. Speight, B.Sc., F.R.I.C., F.I.M.

SYNOPSIS

Previous work on the boron-oxygen equilibrium in liquid iron and evidence of boron pick-up from the fortuitous presence of borates in high-frequency and arc furnace linings had suggested the possibility of adding boron to steel by reduction from a slag containing boric oxide. This method has been investigated as an alternative to the commercial boron addition alloys in a series of laboratory experiments and it has been shown that boron can be introduced into steel from a borate and that the boron so added can be made effective in providing improved mechanical properties of boron steels. These properties can be achieved only by having the correct amount of boron present in the correct mode of occurrence, and the means adopted and the underlying chemical theory for ensuring the desirable occurrence of the boron are described. The laboratory techniques have yet to be applied on a commercial scale, but practical recommendations for the addition of boron by this method in various steelmaking practices are outlined.

The author, in presenting the paper, drew attention to an error in the third complete paragraph of the first column on page 153, where the formula for sodium borate was given as $Na_2B_2O_7$, whereas it should be $Na_2B_4O_7$. That error also altered the calculated yield of boron given in the following paragraph, halving the figures.

DISCUSSION

Mr. D. A. Oliver (B.S.A. Group Research Centre) : These results arise from a chance observation, and I feel that some very important results have flowed from following this chance observation of an apparent contamination of a steel by a minute amount of boron from a furnace lining or even from the practice of protecting the furnace lining during shutdown periods. I notice that the author was very cautious in referring to what he calls the metallic boron, the effective boron, which is acid-soluble and which, I think, he referred to as being in solid solution. Would he agree that probably this boron would fairly readily form carbides, or perhaps go into solid solution in the carbides ? It might form intermetallics with the iron base present, and in fact it might do quite a number of things. I cannot help thinking that it is a little improbable that it would be present without, shall we say, some of its chemical affinities being satisfied.

One matter that interested me very considerably was the author's recommended deoxidation practices. This is a subject on which at one time I had very strong views, and I think that it is a subject which is probably worthy of some real discussion. In general I am strongly against deoxidising any steel with aluminium if it is possible to avoid it. In general in a killed steel the effect of aluminium deoxidation, in my experience, is to produce massive inclusions in odd spots, leaving the rest of the steel abnormally clean. From many points of view, especially in responsible engineering components, one would as a rule prefer a very fine dispersion of unavoidable oxides or non-metallic inclusions rather than a very clean steel with a few massive inclusions. That line of thought caused me some years ago to follow up the potentialities of deoxidising as far as possible with zirconium whenever I wanted a really strong deoxidiser. I admit that zirconium is not quite so powerful as aluminium. That leads me to another point. I see no objection to the procedure recommended at the top of page 153 to start with, namely, 1 lb of aluminium per ton before the slag treatment. On the other hand, I was staggered to find that that is followed up by another addition of 2 lb of aluminium per ton, and finally by an addition of ferro-titanium. The ferro-titanium recommended is again very heavy, in my view, and there would appear to be the risk of what is popularly called titanium cyanonitride, which I think is a wrong term. One gets a solid solution of titanium carbide and titanium nitride in very angular, sharp little pink crystals. That is one reason why I prefer to avoid titanium and to avoid excessive aluminium.

Holding these views, I should like to ask the author what he would think of a régime such as the following : initial deoxidation with ½ lb of aluminium per ton, mixed with or simultaneously added with the equivalent of ½ lb of calcium in the form of calcium-silicon-manganese. That combination of aluminium and CaSiMn I have found in the past to be very effective. The calcium cleanses the steel. Calcium is a grain coarsener, while aluminium is a grain refiner. The two apparently fight, but in general the aluminium wins. It results in a thoroughly clean steel. Finally, instead of titanium I should prefer the addition of silico-zirconium, because the zirconium will fix the nitrogen and certainly stabilise the steel against reoxidation, and the inclusions, if any, will be finely dispersed. Zirconium has another advantage, in that if any glassy silicates survive this ordeal the zirconium will tend to disperse them by attacking them and turning them into smaller particles.

It may well be that in this country we are just moving into the phase when boron can be used intelligently, as distinct from merely being added without a very clear idea of what the advantages are. Without attempting to be a prophet, I think that it is quite evident that as this country is forced to use steels with less and less alloy, if only from the point of view of keeping the cost down and meeting external world competition, we shall find that a controlled addition of boron can be most helpful.

Dr. W. Sachs (London and Scandinavian Metallurgical Company, Ltd.) : One of the great difficulties in using boron in steel, and, I may say, also in making boron alloys for the steel works, is the analytical side, and the work of Mr. Speight and his colleagues in this respect is really very astonishing, when we bear in mind that it may be a question of 0·0001 per cent of boron, and in many cases this little fraction is subdivided into two distinct parts. I understand from the paper that Mr. Speight can make a differentiation between the soluble and the insoluble boron, but he obviously cannot make a differentiation on the analytical side between the soluble boron present as boron oxide and that in metallic form and for this reason he has to use indirect methods to make the differentiation between the two soluble forms of boron, but I should like him to confirm that. I should also like to know whether he employs the usual colorimetric method for the determination of boron in these small quantities, and whether that applies to the insoluble as well as to the soluble variety.

The second point is that the differentiation into three classes which Mr. Speight makes seems to indicate that he gets very much deeper into the problem than the Americans do. I know from American friends of ours that they recommend to the steel works, in order to get round the boron analysis difficulty, that they should determine the free nitrogen content in steel and do away with all boron analysis. That is obviously an easy way out. But, according to Mr. Speight's findings, it would lead to nothing, but would mean that this figure is not indicative of the efficiency of the boron treatment ; because, even if the nitrogen is all combined by other elements than boron, that does not say that there is free boron in soluble form available, which really has the beneficial effect.

I come now to a few metallurgical questions with regard to the reactions which take place. On page 149 Mr. Speight assumes that the aluminium goes for the oxygen and the titanium and zirconium for the nitrogen. That is certainly in line with the theory, but I wonder whether one can really assume that if all three elements are present they split up their forces in such a way that the aluminium goes for the oxygen and the titanium and zirconium for the nitrogen. On page 151, where he mentions how the boron goes into the metal, I wonder what mechanism of reduction takes place. Mr. Speight works

with a more or less oxidic slag, and he gets some boron into the slag and some into the metal. Afterwards he finds that the boron in the metal is present in the form of boron oxide. Is it right to assume, therefore, that the boron is properly reduced into the metal in the first instance and is then oxidised again in the metal by some residual oxygen ? It is difficult to see how aluminium and titanium, which are added afterwards, could work in this direction unless there is a direct solubility of boron oxide in steel, as to which I do not know. I assume that Mr. Speight will be of the opinion that a real reduction takes place and oxidation afterwards. In the same connection he raises on page 150 the question of boron versus aluminium as a deoxidiser, on the basis of earlier work by other authors. I feel that there can be no doubt that boron is a much lesser deoxidiser than aluminium, because boron oxide can easily be reduced by aluminium. That is how boron alloys are made. Aluminium is about the only reducing agent which can be used for the commercial manufacture of boron alloys with a reasonable yield.

Mr. W. E. Bardgett (United Steel Companies, Ltd.) : Our understanding of the technique and the control of boron additions to steel has advanced very considerably since the war years, when I think that the first major effort was made to assess the effect of boron on the mechanical properties of steels. Mr. Speight has pointed out the importance of deoxidising and denitrogenising. This latest technique is a very interesting development and one of considerable importance from the economic standpoint.

The experience of the United Steel Companies has been almost entirely related to the production of " Fortiweld " steel, and it is of interest to mention that this steel has been made in the high-frequency furnace, in the arc furnace and in the open-hearth furnace in both cold and hot metal processes. The effect of boron on this low-carbon, 0·5 per cent molybdenum steel is quite different from that in the case of increased hardenability. This 0·5 per cent molybdenum steel is probably the only exception to the general rule that boron is added to increase hardenability. However, whatever the purpose of the boron addition the technique of its addition remains, of course, the same. Some of our earlier views concerning the effect of boron on hardenable steels may require certain modifications. For instance, it was considered in the early days that the control which one had over the boron addition was much more difficult than the control which one had in adding the usual ferro alloys. Our investigations were done on small, 18 lb high-frequency furnaces, but Mr. Speight was able to build up from that experience to other melting processes and, I can say, with complete success at the first attempt in every case. One cannot simply add boron as a ferro-alloy and expect satisfactory results, but there is no hit-and-miss about it provided that the necessary precautions are taken to ensure that the boron is in the effective form, and with experience it is possible to obtain really surprising control over the boron content, in spite of the very small amount that there is there. Certain variable and erratic results were obtained in the earlier work, and this may to some extent be explained by our lack of control at that time ; but there is a further point of interest. Recent American work has shown that the advantages of boron addition relate only to the steel when comparisons are made on the basis of 100 per cent martensite ; that is, the boron steel must be fully hardened. If it is not fully hardened, the properties are probably inferior to those of the boron-free steel. This, of course, reduces the section size on which we at one time thought it possible to obtain advantages in boron steels.

There is a further important conclusion to which we came in the early work. I think that I am right in saying that at that time, as a result of the work done, we considered that En 16 steel could not be upgraded to the next higher grade, i.e. En 17, by the addition of boron. The effect of boron on particular American grades is very difficult to assess, because the Americans do not seem to have carried out tests on a particular grade with and without boron ; rather do they appear to have designed the boron steel to give hardenabilities equivalent to those of steel of higher alloy content. However, it is quite clear that boron does increase the hardenability of certain steels. I say " certain steels " because there are very distinct limitations. It is usually added to low alloy steels, but, to give one limitation, I might refer to carbon content. The effect of boron decreases with increasing carbon content, and with the eutectoid composition the effect is nil, so that there is a bigger effect at lower carbon levels and a greater advantage.

Dr. L. Reeve (Appleby-Frodingham Steel Company) : I have been asked to give a little information on that side of boron steels with which I have had the closest association, which is their actual production in open-hearth furnaces. As many of you here will know, we at Appleby-Frodingham have made a fairly substantial tonnage of the manganese-molybdenum-boron steel in " Fortiweld," and there are a few points about that production which may be of some interest. While we have not reached the stage of being out of ferro-boron, we have seriously discussed the possibility of making steel in the open-hearth furnace by the borax slag procedure. I do not know whether we shall ever do it, but theoretically I think that it is possible, and under tilting furnace conditions with no slag coming over it is more likely to be successful than in fixed furnace conditions. We have not used that method up to now ; the greater part of our steels have been made with ferro-boron and other deoxidisers. We have now almost given up the use of complex deoxidisers with better results by and large.

With regard to the difficulty or ease of hitting the boron content, that was what we were afraid of when we went into normal production and, incidentally, under normal shift conditions. The specification is 0·0015 per cent to 0·004 per cent. of effective soluble boron. We aim at 0·0025 per cent of soluble boron. In a fairly substantial tonnage of steel, in 90 per cent of the cases we have hit between 0·0020 per cent and 0·0030 per cent, and in the other 10 per cent we were so close that it is hardly worth calling them exceptions, the lowest being 0·0018 per cent and the highest 0·0032 per cent. Under those conditions, apart from some minor troubles when we first started we have had no substantial difficulty in meeting the mechanical test specifications, which, as you know, involve a very high yield point and proof stress.

The second paper for discussion was :—

EFFECT OF DIRECTION OF ROLLING, DIRECTION OF STRAINING, AND AGEING ON THE MECHANICAL PROPERTIES OF A MILD STEEL PLATE

By Constance F. Tipper, M.A., Sc.D.

Synopsis

A series of experiments was carried out on mild steel plate to determine the effect of plastic strain and ageing on notch-impact results and yield point, with the special purpose of investigating directional effects.

Direction of rolling was found to be most significant in Izod-impact tests, the lowering of these values after prestrain being chiefly due to work-hardening and strain ageing. These factors also raised the yield and ultimate tensile stresses and caused loss of ductility.

Direction of straining was found to affect the yield chiefly, both in value and shape. No satisfactory explanation could be found to account for the absence of a recovered yield after ageing.

Discussion

Mr. W. Barr (Colvilles, Ltd.) : On page 145 of the paper, discussing the Izod test results, Dr. Tipper says : " The first effect of the prestrain is to lower all the values of energy absorption, particularly in the transition range." We know that if we take a piece of steel which after 10 per cent of prestrain will break with a fibrous fracture, the reduction in energy absorbed is only of the order of 5 per cent. I think that this statement, which is somewhat confusing, arises from the method of interpreting Fig. 1 in the paper. In that figure we have the temperature/impact curve in the direction of rolling, lengthwise, and below it the author shows a series of points. I think that the author has made a mistake in assuming or implying that this transition temperature is some fundamental characteristic of the material. I cannot see why the author did not simply draw a curve through those points. What is happening is that the 10 per cent of prestrain is shifting the transition temperature to a higher temperature. I think that is important. When the material breaks with a fibrous fracture the reduction in energy absorbed is only about 5 per cent. There is a statement on page 146 which shook me a little, where at the top of the second column the author says : " Treatment at 650 deg. Cent. has removed all effects of strain. The high yield stress may be attributed to refinement of the ferrite." I am particularly concerned with the first part of that statement, that " Treatment at 650 deg. Cent. has removed all effects of strain." In this instance the author is dealing with tensile tests only, but that statement does imply that this treatment at 650 deg. Cent. is removing *all* effects, including the notch impact effects, which certainly is not true. We have found many times recently in connection with the supply of these particularly notch-tough steels that the question has arisen of the work which was put on these steels when they left the steelmaker. The user asks for steels of guaranteed notch ductility, but when they go into the fabricating shop a considerable amount of cold work may be put on them, so that it is obvious that this is a matter which requires looking into. We carried out a considerable amount of work in collaboration with fabricators on that precise problem, and we found that a stress relieving treatment was quite inadequate to remove the effect of this cold work or prestrain as far as notch ductility is concerned ; in other words, it did not restore the transition temperature to its original value in the as-supplied condition. I would call the author's attention in regard to that to an important paper which appeared in the American *Welding Journal* for August, 1949, on the effect of fabricating treatments on steels used for pressure vessels, which brings out that point.

Mr. M. W. Thring (B.I.S.R.A.) : As I see it, this paper begins to make a pier on the bridge which has to be built across the river which separates metal physics from metallurgy and engineering, and that bridge is one of the most important things which is going to come into being in the next five years, or at least I hope that it will be built within that time. On one side of this river we have the pure metal physics, which is the dislocation theory and the various developments of the dislocation theory, work which is mainly at the moment concerned with very simple pure metals, single crystals, mainly hexagonal or

face-centred cubic. We take one step towards greater complication when we get to the work of Cottrell, which is concerned with iron with a very little carbon in it, rather less carbon than the amount mentioned in the paper which Dr. Tipper talks about. Cottrell usually works with 0·02 per cent carbon, whereas this has 0·12 per cent, which is of some importance. Then we come to the polycrystalline material, the third pier of this bridge, but again, however, with the dislocations anchored by small quantities of carbon and nitrogen, as in the Cottrell theory. The fourth stage—and I think that this paper is halfway between the fourth and fifth—is polycrystalline iron with more carbon and with a definite metallurgical structure with pearlite and martensite and ferrite coming into it. At the fifth stage dirt is put into the steel. That comes partly into this paper, where we have non-metallic inclusions. Each of those five stages between metal physics and metallurgy and engineering has its own appropriate theories.

As I have said, the first stage, the pure metal physics, has the theory of dislocations, which has made remarkable strides in the last few years and is getting so exciting that metallurgists have to take a good deal of notice of it, as Dr. Tipper does in her paper. Particularly in that metal physics world this new idea which has come up of locking by cross-slip is very important. It is true that it has not been studied with the body-centred cubic crystals, but only so far with face-centred cubic, but it could happen with the other. It may be one of the possible explanations of the author's results, because she mentions the difficulty that if you have slip-lines at 45 deg. and also at 45 deg. the other way: they should work equally for straining at right-angles, but when those two sets of slip-lines begin to lock each other that does not apply, because the way in which they lock for strains in one direction will not be the same as the way in which they lock for strains in the other direction. We have there a possible explanation of the results.

At the second stage, the Cottrell stage, Professor Cottrell has already given his views. Personally, I am inclined to think that the particular phenomenon with which we are concerned here is not a Cottrell phenomenon, and that the yield point in these specimens is not due to the Cottrell mechanism at all, but probably to the higher quantities of carbon and to a metallurgical phenomenon, but that is only my opinion. One could try to explain these results on any one of three theories: on the theory of the dislocations in the two planes locking each other, and that locking being, of course, inappropriate for the pulling in the direction at right angles; or by the Cottrell theory as set out in the written communication read by Dr. Tipper; or as a metallurgical effect, as due to the presence of carbon in larger quantities, which gives a metallurgical structure which is in some way rearranged by the straining.

That is why I do not like the micro-crack theory which Dr. Tipper mentions; I think that it should be a micro-strong-plate theory rather than a micro-weak-plate theory. It is an arrangement in the metal by the straining of some things which resist movement of slip-lines rather than a rearrangement of weaknesses. That is the sort of direction in which I think that this can probably be explained, and therefore I should like to ask Dr. Tipper to look at the structure of the metal which she is deforming by all possible means.

Dr. B. B. Hundy (British Iron and Steel Research Association): In her most interesting paper Dr. Tipper refers to work carried out at Massachusetts Institute of Technology. I was associated with this work, and I should like to take this opportunity of outlining our ideas on this point. We think that a cast metal contains a number of randomly-oriented micro-cracks. (As these are not obvious under the microscope, perhaps they should be called sub-micro-cracks; but, having made this point clearly, it is more convenient to refer to them as micro-cracks.) We consider that the deformation of the cast metal will probably cause fresh micro-cracks to form, and all these cracks, regardless of their origin, will be aligned in the direction of metal flow during working. This crack structure can be found in most ductile metals, and handling does not seem to affect the cracks. The true fracture stress and the reduction in area to fracture were affected by this crack structure, but we found no appreciable effect on the yield strength or the u.t.s. Most of our evidence for the cracks is indirect, but the examination of a number of ductile metals tested in tension showed some holes in the fracture surface.

The final paper presented to the meeting was "The Rapid Softening of Cold-Drawn Austenitic Stainless Steels," by Mr. F. A. Hodierne and Dr. C. E. Homer. It described work undertaken to provide the metallurgical basis for the rapid softening process.

Eastham Oil Dock

No. I

A vast amount of civil engineering work has been carried out since the war as part of the programme of expansion of the oil industry in this country. Apart from the extensive site development works at the various new refineries, it has also been necessary to provide berthing facilities for tankers in a number of cases. The largest project of this kind is probably the oil dock at Eastham, in the Mersey estuary and a short distance from Stanlow refinery, which is described below.

THE oil dock which the Manchester Ship Canal Company is building at Eastham, at the entrance of the Manchester Ship Canal, has now been under construction for three years. Its progress has been noted in these columns in our Annual Review articles during that period, but the dock has now reached a stage where a more detailed account of it may be given. It is shown in plan in the accompanying diagram, Fig. 1, from which it will be observed that the dock is approximately square, with berths for four tankers, giving a water area of 18½ acres, and with an entrance lock leading into the River Mersey. The spoil excavated from the dock forms three deposit grounds which will be graded and soiled so that they may be used agriculturally when the dock is completed. During construction a substantial cofferdam protected the entrance lock from the River Mersey. The first stage of the work involved the building of a power station to supply hydraulic power for operating the sluices of the new entrance lock and the existing locks of the ship canal; when it was completed, the old power station adjoined to the ship canal locks was demolished. The work has also involved the construction of pipelines leading to a tank farm, and to Stanlow oil refinery which is about 6 miles away, and the diversion of a sewer outfall.

The new dock will have a depth of water of 40ft and will be able to accommodate tankers of the largest size. It is excavated from sandstone and will have mass concrete walls, the bottom being left as excavated. The entrance lock has an effective length of 807ft and a width of 100ft; it is to be closed by three caisson gates so that locking chambers with lengths of about 180ft and 610ft may be utilised.

At the present time excavation for the oil dock is substantially completed, the total volume involved being about 3¼ million cubic yards. Construction of the entrance lock is also nearly finished, and the first of the three caisson gates is in position. Good progress has been made with the walls of the dock itself, although a substantial part of this work remains to be carried out. The total volume of concrete required for the completed project is about 370,000 cubic yards.

Excavation

Construction of the oil dock at Eastham has departed from conventional practice with some of the plant and methods employed, as is exemplified by the system of spoil removal adopted. The most economical method of handling the 3¼ million cubic yards of excavation, about half of which was in rock (sandstone), was considered to be that of installing conveyor belts from the dock to the deposit grounds. This installation is unusually large and is thought to be an innovation in handling excavation on this scale.

The rock is blasted as necessary, and excavated by dragline, 2½ cubic yard machines being employed, generally with seven machines of various sizes on the site engaged on excavation and other duties. The draglines deposit their

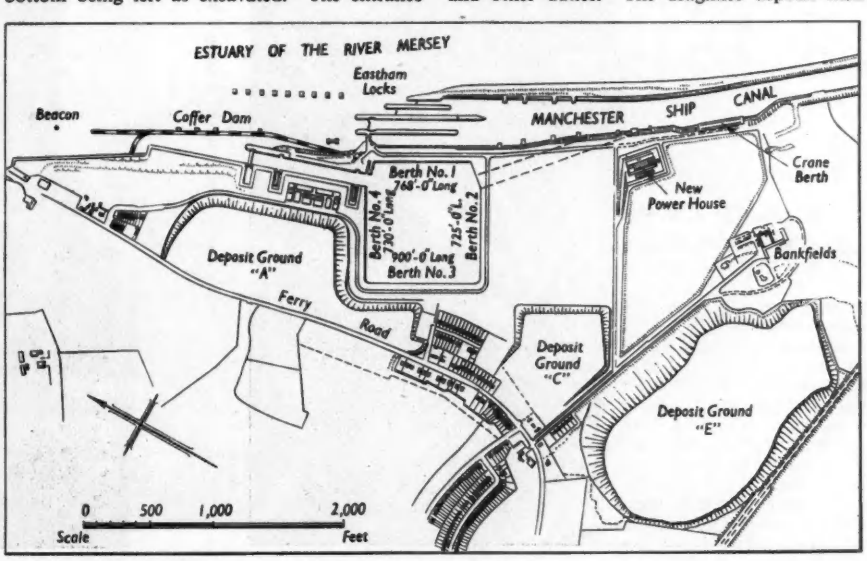


Fig. 1—Eastham Oil Dock

EXCAVATION PLANT AT EASTHAM OIL DOCK

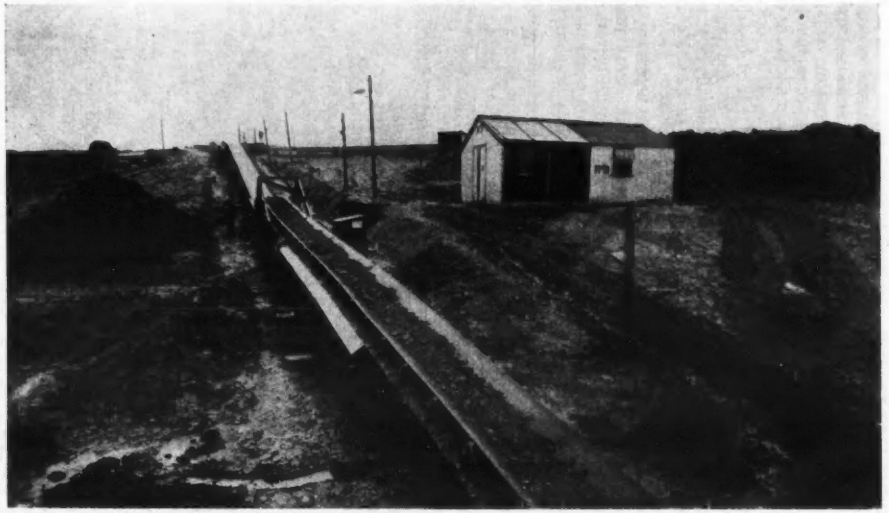


Fig. 2—Tandem Point on Tipping Conveyor

Fig. 3—Run of Conveyor to Tipping Area

Fig. 4—Driving Head and Jib at Transfer Point

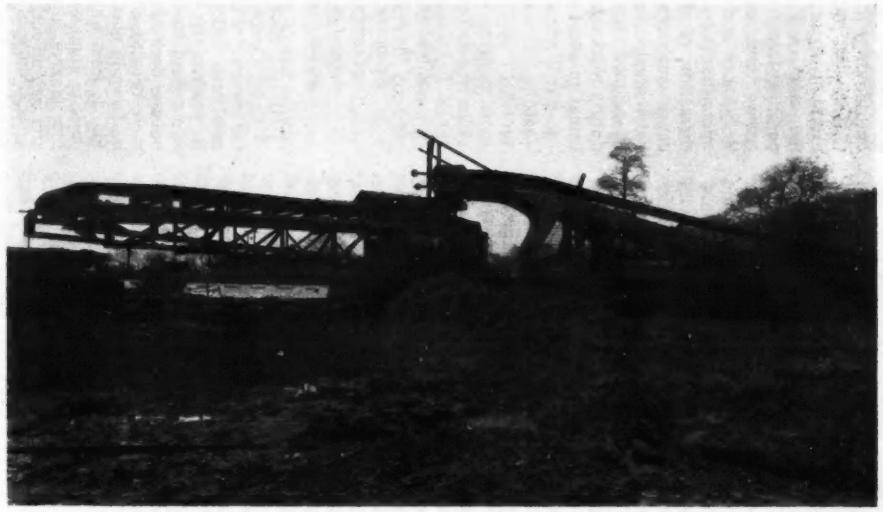


Fig. 5—Throw-off Carriage Feeding Shuttle Conveyor

spoil into a hopper of about 12 cubic yards capacity, which straddles a 42in troughed conveyor belt. Generally, two draglines are positioned to supply each hopper, one on each side, so that a ridge is formed with the conveyor along the top of it. The hopper and conveyor head underneath it are on rails, and can be moved back as the excavation proceeds and the end of the ridge is dug away. The hoppers are fitted with plate feeders which draw off the spoil at the required rate of handling. The hoppers are shown in Figs. 3 and 4. The work was arranged so that, whilst the excavation was in full swing, two or three conveyor belts led to a central point where the spoil was transferred to a single conveyor leading to the deposit ground ; however, the arrangement of the conveyor was readily adaptable to the particular needs of each stage of the work.

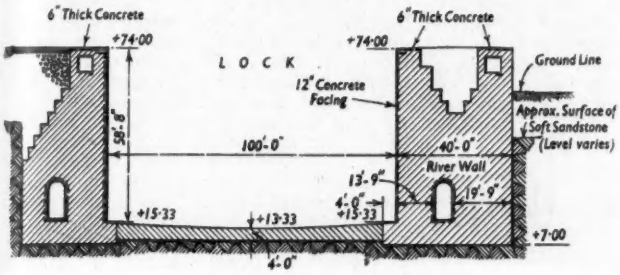


Fig. 6—Cross Section of Entrance Lock

At the deposit grounds, throw-off carriages mounted on rails tip the material on to spreader conveyors. The latter are in effect small portable conveyors carried by the throw-off carriages, which can revolve through 220 deg. and are thus capable of disposing spoil evenly over a wide area. A throw-off carriage with its spreader conveyor is shown in Fig. 5, but in this case the spoil is being transferred to a shuttle conveyor, which runs across the deposit ground. By the use of such shuttle conveyors, each terminating in a throw-off carriage and spreader conveyor as described above, the exact manner in which the deposit ground was built up could be controlled. The building of a dump with a flat top which could later be used for agriculture was thus ensured, with only a minimum of final grading by bulldozer.

The total length of the conveyors used for the excavation is about 2 miles, the largest " haul " being about ¾ of a mile from the dock to the deposit grounds ; twenty-one conveyors have been installed altogether, with seventeen in permanent use. The capacity of this system was estimated at 480 tons per hour ; in practice, 25,000 cubic yards was considered to be a good weekly progress figure for two draglines, excavating to one hopper as described above and working two shifts for six days. The longest single conveyor on the site is 1400ft long. The conveyor framework is all of troughed construction, with belt widths of 36in and 42in. The conveyors are driven by 60 h.p. and 80 h.p. electric motors incorporated in " Goliath 6 " and " Goliath 80 " driving heads (of designs which have been in use, for instance, in collieries for many years), giving a belt speed of 280ft per minute. Impact idlers are fitted at all loading and transfer points to reduce wear. The experience gained with this conveyor system at Eastham oil dock has indicated that more than a million cubic yards of material can be transported on a belt before it need be replaced, and it is hoped to complete the excavation after using only two sets of belts. Sumps have been provided for pumping out the excavation area, but only moderate amounts of pumping have been necessary.

The Entrance Lock

The first part of the work at Eastham was concentrated on the entrance lock, which is now nearly completed. As may be observed from the plan, Fig. 1, the river entrance was sealed from the river by a large cofferdam. This dam consisted of a rubble bank with two lines of steel sheet piles driven in it. The lines of piles were 18ft apart, the minimum top width of the cofferdam being 18ft, and the side slopes were 1 : 1. The dam was built 9ft above H.W.O.S.T. and had a maximum height above the river bed of 35ft and a base width of 70ft. The steel sheet piles were 35ft long. A single line of steel sheet piles was driven along the river bank and the bank of the Manchester Ship Canal to seal off that side of the work. On completion of the new power station, the old power station adjacent to the entrance locks of the canal was taken out of service, allowing work in the entrance lock to go ahead.

A cross section of the lock is shown in Fig. 6 ; in this illustration the levels are above the Manchester Ship Canal datum which is 50ft below the Ordnance Datum. Thus, the mean tide level is at +50, with an average range of 27ft at spring tides and 19ft at neaps in the river. The general design of the mass concrete walls of the lock and of the " dished " invert may be appreciated from the cross section. Drains to relieve uplift pressure when the lock is dewatered have been provided at intervals in the invert. Two qualities of concrete have been employed—for hearting and facing—and the meeting faces of the lock gate grooves are of granite. Details of the three caisson gates are given in the next section of this article. Water enters or leaves the lock chambers through culverts in the lock walls, as may be observed in the cross section (the upper culvert is for various ancillary services), which lead to a number of openings in the lock walls. A point of interest is that the culverts are controlled by hydraulically operated sluice paddles made of greenheart ; such paddles have given good service in other of the Manchester Ship Canal Company's installations, and were therefore selected as being most suitable. Fig. 8 shows a greenheart paddle. Each sluice can be isolated for maintenance by emplacing steel dams in dummy sluices which have been constructed on each side of it.

Fig. 8—Greenheart Sluice Paddle

This part of the work has also involved the construction of the three recesses or cambers for the caissons, and of an entrance wall, of the same general cross section as the lock walls, 709ft long from the river sill of the lock, and with a return of 125ft at the end of it. This wall is fitted with timber fendering. On the river side of the lock, the wall was built as a combined lock wall and river walls for about half the length of the lock, and it is this section of the lock which is shown in Fig. 6.

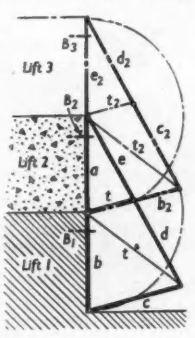


Fig. 9—Diagram of Shuttering

A central concrete plant has been installed on the landward side of the entrance lock at about the middle of its length. It consists of weigh-batching plant and two 2 cubic yard mixers. Each mixer supplied a 6in concrete pump for emplacing the concrete in the entrance lock. The walls were poured in 4ft lifts, with gaps of 5ft left at intervals of 65ft, and concreted later when the main body of concrete had had sufficient time to contract. The shuttering used for this work, and for the walls of the main dock, is an ingenious development of the well-known climbing design, in which bolts are placed in each new lift of concrete and used to anchor the soldiers

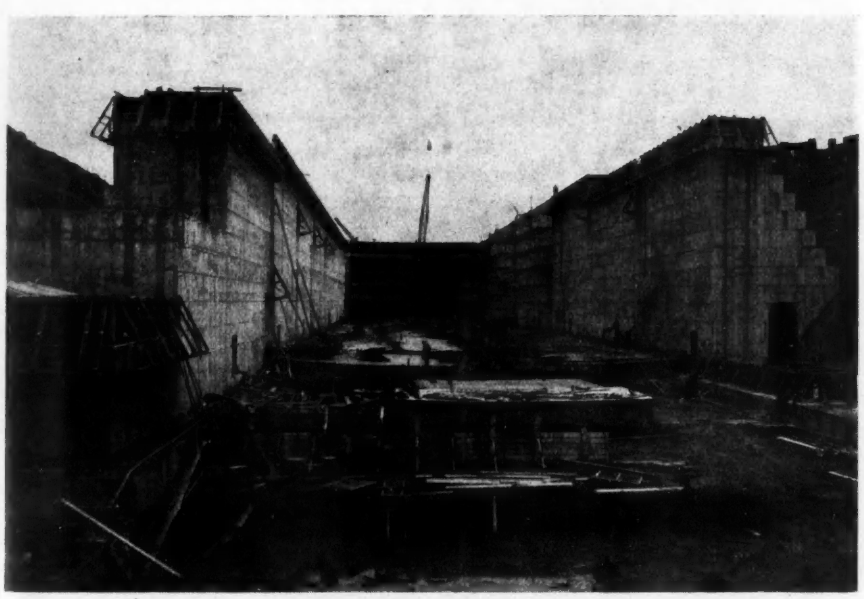


Fig. 7—Progress of Entrance Lock in March, 1952

of the shuttering for the next lift. The diagram—Fig. 9—indicates the construction of the soldiers, each of which is made up of a double frame of rolled steel channels in the form of an isosceles triangle. The five members are pinned together, and the frame is held rigid by tightening the turnbuckles on the two ties *t*. By adjusting these ties, the member *a* can be given a slight tilt inwards, so that it will be restored exactly to the vertical position by the force exerted by the wet concrete. The soldiers are placed at 4ft 6in centres and steel-framed plywood shuttering panels are fixed between the members *a*. When the new lift (lift 2) has set, the bolt *B* and the clamps holding the panels are removed and the ties are slackened. The soldier is then repositioned for the next lift (lift 3) by readjusting the frame, leaving the member *a* in the same position, and rotating the member *e* to be vertically above it, the other members of the frame taking up the positions indicated in the diagram. The ties are then repositioned to make the frame rigid in its new position. The shuttering panels are double sided, and can be simply rotated to each new position by a pin and lug arrangement. They are shown in use in the progress photograph reproduced in Fig. 7, which gives a good idea of the work in the lock, generally.

(*To be continued*)

The Smithfield Show and Agricultural Machinery Exhibition

No. III—(*Concluded from page 792, December 12th*)

THE Smithfield Show and Agricultural Exhibition, at Earls Court, London, ended last Friday evening, December 12th, having been open since the preceding Monday. Although the attendance was somewhat below the record achieved last year, there was no lessening of interest in the exhibits, and in particular in the array of agricultural machinery, implements and other equipment on the numerous trade stands. The recorded attendance on the five days of the Show was 59,342, although we understand that that figure does not include the number of overseas visitors, of whom there were several hundreds. We conclude below our account of some of the new machines and implements which were exhibited.

Ransomes, Sims and Jefferies, Ltd.

An implement of particular interest to smallholders is the "Vibro-Hoe," which has just been introduced by Ransomes, Sims and Jefferies, Ltd., Orwell Works, Ipswich. This hoe, which is illustrated in Fig. 16, has been constructed to the design of the makers and of Mr. Wallace Henderson. It reproduces as nearly as possible the action of hand hoeing, and accomplishes the same results owing to the fact that instead of fixed or rotary blades, the "Vibro-Hoe" has reciprocating blades which move backwards and forwards through a small arc at a speed directly proportional to the rate of travel. This reciprocating motion automatically frees the blades of matted weeds and roots and thus eliminates hold-up of the work through clogging. Moreover, it enables the hoe to work close up to the rows without spilling soil over the growing plants. As may be noted in our illustration, a length of chain is attached to each blade, which assists pulverisation of severed weeds, shaking them free of soil. The hoe is powered by a 98 c.c. Villiers two-stroke engine and the design incorporates an automatic clutch which enables the hoe to be controlled by one lever only. The handles, as well as being adjustable for height, can be adjusted laterally to allow the operator to walk in an adjoining row. It is also possible to fit five cultivating tines working on the "vibro" principle.

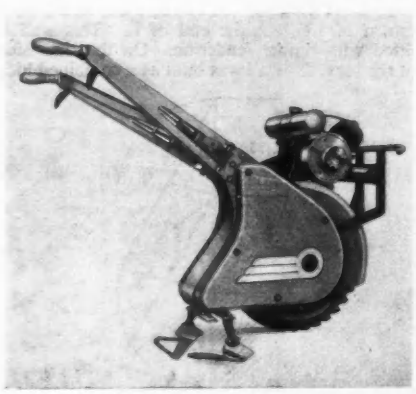


Fig. 16—The "Vibro-Hoe"—Ransomes, Sims and Jefferies

In addition to a selection of the mounted and trailing ploughs, cultivators, mounted disc harrows and the "MG.5" track tractor which the firm manufactures, there were shown the "Cropguard" tractor-mounted high-volume sprayer, equipped with a 100 gallon tank, and the "Minor" peanut picker, which is driven by an electric motor. Another machine of particular interest on the Ransomes stand was a 4ft combine-harvester of Swedish origin. It is a tractor-powered machine which is now to be produced in this country by Ransomes, Sims and Jefferies, Ltd., under licence granted by Bolinder-Munktell.

Hayters, Ltd.

The front-mounted rotary grass cutter, illustrated by Fig. 17, was the principal exhibit of Hayters, Ltd., Spellbrook, Bishop's Stortford, Herts. It is made for use with "Fordson Major," Ferguson, David Brown and Allis Chalmers tractors, and is specially suitable for work in orchards, plantations, parks and other places where difficult mowing conditions may be encountered. As will be noted from the illustration, attachment to the front of the tractor is by a simple frame, and the cutter itself is essentially the same as the rear-mounted machine produced by the firm. The three cutter heads are steel shafts, running in heavy ball races, and to each of them there is fixed in a horizontal position a specially shaped dural plate with four cutter blades bolted to it. Power is taken from the tractor by the belt pulley attachment, a five-groove pulley being fitted instead of the usual flat pulley. Transmission to the main countershaft of the machine is by five endless vee belts, and the final drive to each of the cutter heads is by belt. The rotation of the cutter heads can be quickly reversed by changing the direction of the belt drive. The machine is mounted on four solid-tyred wheels with rotary ball-bearing castors, and there is a guard over the whole outfit to protect the operator from any loose stones that may be thrown up by the cutter blades.

A 24in. motor scythe was also exhibited by this firm. It operates on the same rotary principle, the cutter blades being affixed to a plate driven by a 1in steel shaft. Again, the transmission is by vee belt, the power unit being a four-stroke Villiers engine.

Another application of the rotary cutter was shown on the stand of Silorators, Ltd., 103, Park Street, London, W.1. It is the "Hayter Silorator" forage harvester, a tractor-operated machine for the pretreatment of green crops for silage, the action of the "Silorator" being to release the juices and break down the cellular structure of the crop. The final assembly of the equipment is being undertaken by Hayters, Ltd.

Whitlock Bros., Ltd.

One of the several new products shown by Whitlock Bros., Ltd., Great Yeldham, Essex, was the "Dinkum Digger" deep trencher and excavator, a photograph of which is reproduced in Fig. 18. This machine has been designed for mounting on the three-point linkage of most tractors equipped with a rear power take-off shaft, and can be used for a variety of jobs concerned with farming, building and the installation of public services. The trencher is operated through a series of hydraulic rams worked by a single pump, mounted in the centre of the machine and driven by the power take-off shaft through a Hardy Spicer universal coupling. The makers claim that the digging ram gives a thrust of over 6 tons to drive the bucket, through hardpan, clay or heavy gravels, to a depth of 7ft. and a width of 2ft. The power is controlled by three levers for digging, lifting and slewing to either side. A foot-operated cut-out valve, in combination with a relief valve, enables full power to be maintained even when digging in

Fig. 17—Front-Mounted Rotary Grass Cutter—Hayters

Fig. 18—" Dinkum Digger " Trencher—Whitlock

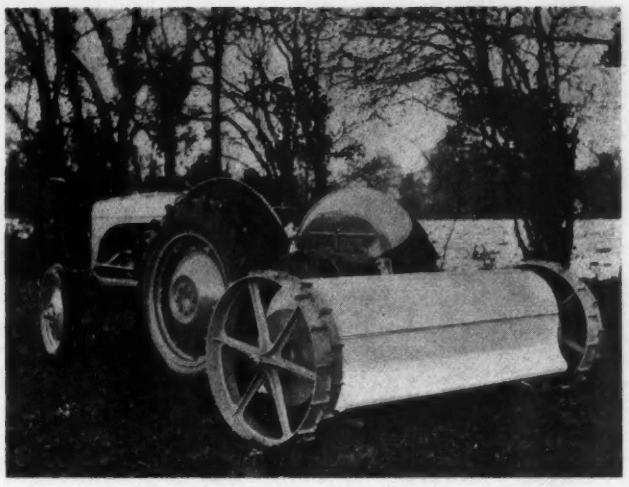


Fig. 19—Plant Thinner—Whitlock

difficult ground. The digging and lifting rams are located above the jib, and are thus immune from damage by soil abrasion. The equipment is assembled on a triangular frame and there are flexible skid pads to support the rear end of the machine while it is in work. In addition, an adjustable compression strut allows the full weight of the tractor's rear end to be used. The standard trenching bucket on the " Dinkum Digger " is 24in wide and has a capacity of 5 cubic feet. The bucket is fitted with replaceable self-sharpening alloy steel teeth and its alloy steel side cutting and sole plates are reversible and renewable. The " Dinkum Digger " is a one-man machine, the tractor seat being reversed for its operation. It advances progressively with the tractor, the trailing sprags obtaining a new grip when digging restarts. The spoil can be deposited on either side of the trench up to an angle of 45 deg. The hydraulic system and mechanisms are lubricated internally by the working fluid, and the whole machine can be quickly locked in the transport position by a single pin. It may be added that other attachments—including muck and root loaders and a grab of 3 cubic feet capacity—are available in place of the trenching bucket.

Another new machine which was shown by Whitlock Bros., Ltd., is the " Campbell-Buckman " rowcrop thinner. This machine, an exterior view of which is reproduced in Fig. 19, has been designed to deal with the thinning of such plants as sugar beet, carrots, cotton, kale, &c., an operation which normally requires a considerable amount of hand labour. The thinner is tractor-drawn, its main frame being mounted on an axle, and the main drive to a layshaft being effected by the land wheels, so that the speed of rotation is synchronised with the speed of travel over the ground. As the tractor moves forward, oscillating hoe arms, which are adjustable for depth of working, are lifted over the rows of plants from one side to the other. When the hoe blades reach their predetermined correct positions relative to the ground and the section of the row to be cut out, spring-loaded pistons automatically operate and bring the blades rapidly down and through the plants, returning the hoe arms back to their normal " at rest " position ready for the next stroke. The thinner illustrated is a four-row machine intended for sugar beet, the hoes being mounted in staggered formation with 22in row widths and 10in row section. The machine can be worked with any tractor with a three-point linkage.

Pest Control, Ltd.

A new trailer spraying machine, which was introduced at the show by Pest Control, Ltd., Harston, Cambridge, is the " Fieldmaster," illustrated in Fig. 20. Basically, it is intended for crop spraying, but there are alternative spray-bar attachments for dealing with fruit trees, hops, and vineyards, and for the use of hand lance equipment. The steel tank, the capacity of which is 100 gallons, is of all-welded construction and is treated internally against corrosion. Provision is made for mechanical agitation of the spray liquid, the agitator shaft which transmits the drive from the tractor power take-off to the pump being carried in two gland bearings fitted to the end plates of the tank. This shaft extends from the rear of the tank, where a flexible coupling transfers the drive to the pump. The pump—known as the " Arun "—is also a new production of Pest Control, Ltd. It is a positive displacement pump, with twin cylinders horizontally opposed, and has a capacity of 15 gallons a minute when working at its maximum pressure of 200 lb per square inch at a speed of 500 r.p.m. All parts of the pump coming into contact with the spray chemical are manufactured from corrosion-resisting materials and the cylinders are vitreous enamel lined. A large filter is fitted in the suction line from the tank to the pump and the pressure line from the pump is led to a manifold, mounted on the rear of the tank, which incorporates the pressure regulator and the air bottle. The spray bar boom assembly is pivoted on cantilever arms from the tank to permit easy height adjustment, and it can be readily secured in any required position. The spray bars, which are in three sections, extend to a width of 22ft 6in and are provided with eyelet tee-jet nozzles for low-volume spraying. Alternative nozzle tips can be fitted when it is required to change over to high-volume spraying. The effective spraying width of the " Fieldmaster " is 24ft, and the side spray bars are camber hinged in the horizontal or vertical planes and can be stowed vertically for travelling.

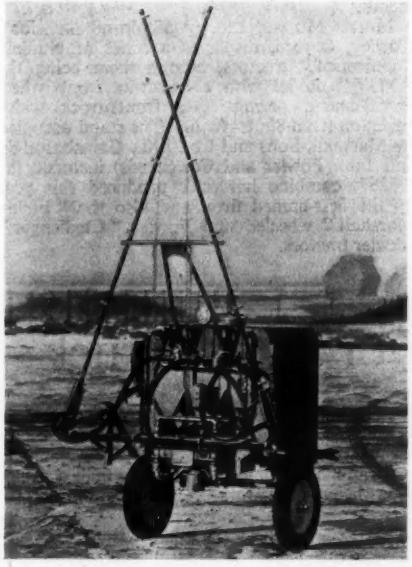


Fig. 20—" Fieldmaster " Sprayer—Pest Control

The whole tank unit is mounted in an all-welded steel chassis which carries, in addition to a parking stand, an adjustable drawbar for attachment to all well-known makes of tractor. The pneumatic tyred wheels are fitted to half axles, the track being adjustable from 42in to 60in.

Scottish Mechanical Light Industries, Ltd.

In Fig. 21 we illustrate a new hammer mill, which was exhibited by Scottish Mechanical Light Industries, Ltd., Scot Mec Works, Ayr. It is known as the " Two-Tonner " and has been designed for operation by a tractor within the 25 h.p. to 40 h.p. range or by diesel or electric drive. The mill incorporates twenty-four swinging hammers, and by the employment of a specially designed fan and air ducting the removal of the ground material is dealt with very efficiently. The equipment also includes a non-magnetic metal eliminator and twelve screens, the perforations of which range from 0·0235in to 1½in. A " bulk feed " top, which extends to a width of 13in, has been provided so that such material as sheaves and dried grass can be dealt with, and a " full sack " combined chute-hopper, fitted with a " Micro " feed gate, enables the flow of grain to be accurately regulated.

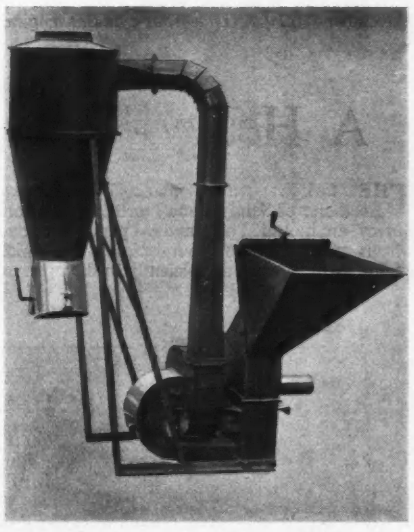


Fig. 21—" Two-Tonner " Hammer Mill—Scottish Mechanical

Some Other Exhibits

As stated in an earlier article, the machinery section of this year's Smithfield Show was outstanding by reason of the many new products which were exhibited for the first time. Those with which we have dealt can be said to be a " representative selection," but there were many

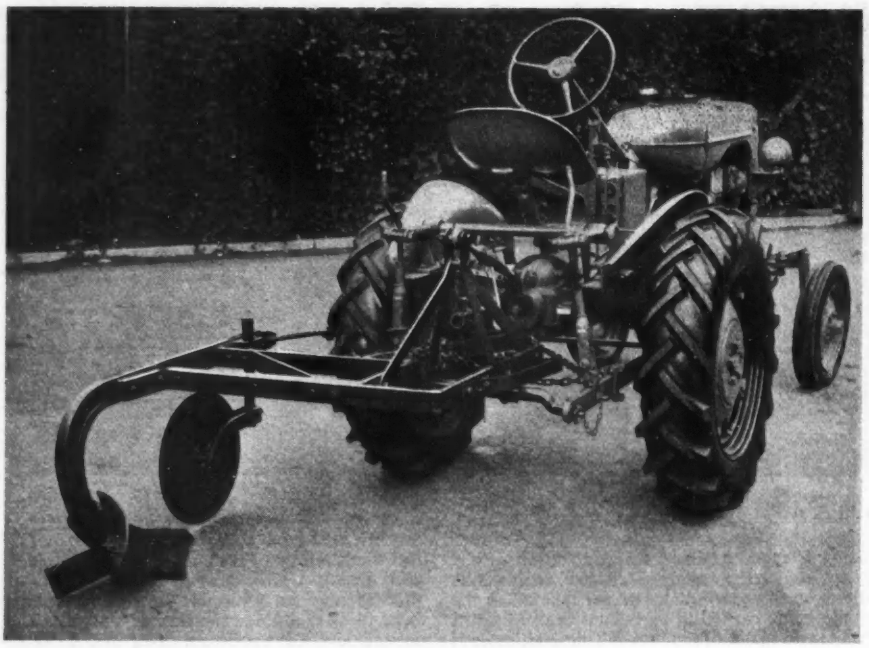


Fig. 22—Headland Plough—Twose

others. Among them, for example, was the single-furrow headland plough (Fig. 22) exhibited by E. V. Twose, Ltd., Lowman Works, Tiverton, Devon. This plough, which is offset to several inches outside the nearside tractor wheel, has a swinging coulter consisting of a cutting disc with a renewable hub, a renewable 12in steel share, and a standard mouldboard. To keep the plough in line with the tractor a tension bar is fitted from the plough to a hub which is bolted to the centre of the rear left-hand tractor wheel.

The engine exhibits included the "L4" industrial and tractor diesel engine, which has been introduced recently by F. Perkins, Ltd., Peterborough, and described in our issue of November 7th. It is a four-cylinder engine, 4¼in bore by 4¼in stroke, and is rated up to 62 b.h.p. at 2000 r.p.m., with a maximum torque of 182 lb-ft. The swept volume is 269·5 cubic inches.

Morris Motors, Ltd. (Agricultural Division), Cowley, Oxford, displayed a series of Nuffield "Universal" tractors, among them being the "M3V" model with a vee-twin front wheel arrangement, permitting a front track width variation from 8in to 10½in. The stand occupied by Marshall, Sons and Co., Ltd., Gainsborough, and John Fowler and Co. (Leeds) included the "626" combine harvester produced this year by the first-named firm, and also the "Field-Marshall" wheeled and Fowler "Challenger" crawler tractors.

A Heavy-Duty Fork Lift Truck

THE fork-lift trucks made by Mathews Brothers, of Sandy Lane North, Wallington, Surrey, are mounted on standard pneumatic road wheels and have high ground clearances, which enable them to work as efficiently in the open on uneven roadways as under the normally more favourable conditions inside industrial establishments. As a further step in its development programme this company has now built a prototype heavy-duty fork-lift truck designed for working under particularly unfavourable ground conditions on open unmade sites. This machine is largely built up from the known and tried standard units used on other of the firm's machines, and it incorporates certain modifications to adapt it for more arduous conditions.

Fork-lift trucks to this new design can be fitted with masts giving lifting heights of 9ft or 12ft with respective capacities of 3500 lb or 3200 lb at 18in outreach. The trucks can be supplied with either petrol or diesel engine drive, and have six forward speeds, ranging up to 20 m.p.h., and two reverse speeds.

A particular point in construction which plays an important part in adapting the truck for bad ground conditions is the use of twin 11·00in by 36in pneumatic "groundgrip" tyres on the front, driving wheels. The rear, steering wheels have 7·50in by 24in pneumatic tyres. The firm's conventional hand-operated steering gear is fitted and the steering axle is a heavy steel section, centre pivoted, trunnion mounted, unit carrying stub axles in bushed king pins. Each front wheel has a vertical movement of 8in. A cast steel radius rod and substantial forged steel steering arms are fitted.

Without its forks the truck is just under 11ft long and it has a normal turning circle of about 14ft radius or 10ft when using steering brakes. As a standard 3ft long forks are fitted, but longer units are available if required.

The mast of high-tensile steel channels is fitted with replaceable rubbing strips and is operated by a hydraulic lifting cylinder through wire ropes. Pressure fluid for the mast lifting and tilting cylinders is supplied by a balanced vane pump driven from the engine.

We recently witnessed a demonstration of the prototype machine on a large open site near the maker's works, and two photographs reproduced on this page show the severity of the tests. With a load of some 3000 lb suspended on the forks the machine was first driven down a series of steep inclines over rough unmade terrain. The machine was then driven up and down and manœuvred on a series of inclines of up to 1 in 2½, on many of which the surface was of loose, uneven soil. It was then taken to an adjoining work site where, with a load of only a few hundredweights on the forks, it was driven around through patches of loose mud 18in or more deep.

Throughout these tests the machine was under the full control of the driver, and despite the severity of the conditions it was completely stable and performed all the tasks to which it was put with a surprising degree of ease and with little or no slipping on the inclines or in the deep mud.

The firm has also designed a fork-lift truck of 2 tons capacity which is mounted on tracks for use under the worst possible ground conditions.

Truck on Incline

Truck Operating in Deep Mud

Construction of a Tubular Steel Skip Bridge

AN interesting example of the problems which are frequently encountered when reconstructing, modifying or extending existing plant at a large steelworks arose when some time ago it was decided to build a new blast-furnace at the Bilston iron and steelworks of Stewarts and Lloyds, Ltd. Two furnaces were being fed by a skip bridge erected on the site on which it had been decided to build the new furnace, and the problem was to build a new bridge in such a way that the existing furnaces could continue to operate whilst the new furnace was under construction. The position chosen for the new bridge was at right angles to the existing skip bridge, and this meant that its path would lie between existing stoves and pass through gas and air mains. Slight modifications were required for the mains, and, as it was considered unwise to impose additional loads on the existing furnaces and connecting bridge, the new structure had to be carried on an "A" frame.

The main contractor for the work was Ashmore, Benson, Pease and Co., Ltd., and the design of a new skip bridge in steel tubing was entrusted to Tubewrights, Ltd., as by adopting tubular construction the weight of the bridge could be kept very low. The design evolved was an open box section structure 13ft wide, 12ft high and 140ft long, weighing some 30 tons.

The site conditions made normal assembly and construction methods impossible, and a falsework of tubular scaffolding was erected on which to build the skip bridge. This scaffolding, some of which can be seen in the photographs of the bridge reproduced on this page, had to be accurately erected to form a true template for the support of the main panel members. Due to the space limitations few facilities were available for pitching the scaffolding to support the upper and lower boom members of the bridge and during the work frequent changes of the original plans were necessary to overcome difficulties as they arose.

The order of erection is given in the following notes. A start was made on the lattice legs of the "A" frame, each leg being built in two halves. Owing to the length involved—about 90ft—it was impossible to make up a leg in one length and thread it into position. Some rather tricky assembly and welding was necessary at the ends of the legs where they fitted into double-jawed base plates.

After fabrication of the half legs, each bottom half was lifted, threaded through and dropped on to the base plate, after which scaffolding was built around to hold it in the correct position. The top half was then threaded through and positioned correctly to line up with the bottom half. A working platform was built round the junction points and welding completed. It was only possible at this stage to add about half of the cross bracings tying the legs together owing to lack of clearance and the necessity of removing some of the existing structures in the way of cross bracing. Sufficient bracing, however, was welded on to ensure that the "A" frame could be positioned correctly.

Owing to the congestion around the site, a 100ft derrick was then used to build the two side girders of the bridge vertically. This was done by building a tower of scaffolding around the girders and stubbing on the main boom members in succession. Welding was carried out at heights of up to 80ft on working platforms provided by the scaffolding. On completion of the main girders it was found that the bleeder on the adjacent No. 4 furnace would interfere with the girder when it was dropped into position, and therefore the right-hand girder had to be foreshortened until such time as the bleeder could be altered at a suitable shut-down date.

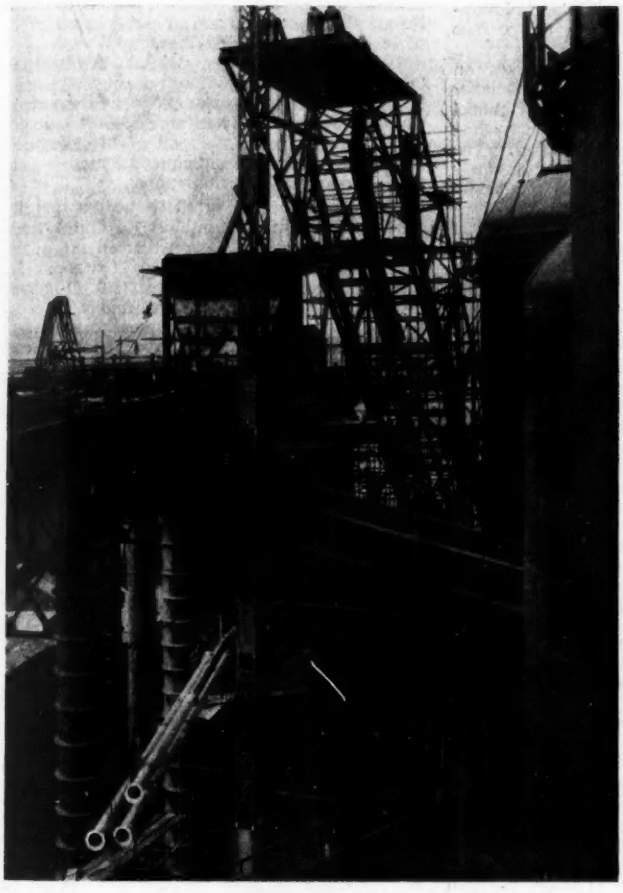
When welding was completed the scaffolding in the way of one girder was removed and the girder lowered by means of the derrick until it rested on its location on the "A" frame. It was then pinned. A similar procedure was followed with the second girder.

A scaffolding grillage was then built around the girder giving support at panel points. The box arrangement of the bridge was then completed working from base to top, using R.S.J. transomes and longitudinals to carry the rails. It will be appreciated that during this time No. 4 furnace was still in operation and at one point, under the wheeling platform, the clearance between the furnace and the outside of the bridge was only 6in. As the welders traversed along the bridge, welding took place nearer the wheeling platform and when the wind blew from the furnace towards the bridge all work had to be stopped owing to gas fumes.

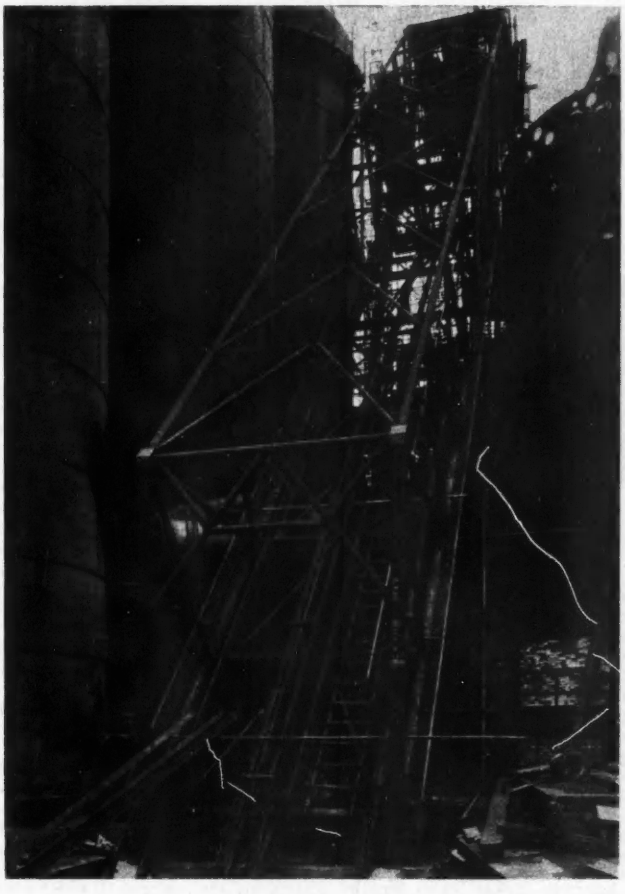
It was, however, necessary to shut down the furnace to modify the bleeder and this eliminated most of the gas trouble. With the alteration to the bleeder it was possible to complete the platform for the hoist. Girders and dumping rails were fixed and as a final precaution, the whole of the bottom deck was plated to prevent material falling through.

A 3ft wide series of ladders and platforms were built at site and fitted to the skip bridge to give easy access to the wheeling platforms and to make easier the handling of any accident cases.

Apart from the pins at the base of the bridge and at each end of the "A" frame and the rails which are bolted to the R.S.J. longitudinals, the



Skip Hoist Platform



Skip Bridge Under Construction Between Stoves

whole bridge is a welded structure. Butt and fillet welds were used following standard welding practice, but several were made under conditions of heat, access and height which caused unusual difficulties, but did not impair the final quality.

As already mentioned, Tubewrights, Ltd., a subsidiary of Stewarts and Lloyds, designed the bridge and "A" frame from information supplied by Ashmore, Benson, Pease and Co., and the work of erection was a joint undertaking with scaffolding by the London and Midland Steel Scaffolding Company, Ltd.

Completion of a Water Supply Scheme in the Edinburgh District

THE Water Department of the Corporation of the City of Edinburgh is responsible for a supply of about 33 m.g.d. to a population of nearly 600,000. The principal sources of supply are various upland gathering grounds, each with its appropriate storage. The largest supply, about 50 per cent of the total, is stored in the Talla reservoir, which is situated on a south bank tributary of the Tweed just above Tweedsmuir. The supply to this reservoir has now been increased by the diversion of two further tributaries—the Fruid and the Menzion—into the reservoir. These two streams run substantially parallel to the Talla, so that the new works have involved an intake on the Fruid and a diversion tunnel to the Menzion intake, the tunnel then continuing on to end in the Talla reservoir.

This new scheme has now been completed and was officially opened on December 5th last. It will add approximately 6 m.g.d. to the supply, which has been necessitated by the increasing demands for water, more especially by industry in the city, and by the incorporation of new districts in the supply areas. The scheme is in effect the first instalment of the second development contemplated by the original Tweed Scheme of the former Edinburgh and District Water Trust of over half a century ago. This scheme provided for the utilisation of the head-waters of Tweed lying above Tweedsmuir in the following stages, viz.: (1) The impounding of the Talla Water in a reservoir of 2800 million gallons capacity; (2) the diversion of the Menzion Burn into Talla reservoir and the impounding of the Fruid Water; (3) the impounding of Tweed.

It was with these ultimate ends in view that the aqueduct to the city, excepting the syphons, was made large enough to carry approximately four times the quantity of water which the then engineering advisers of the Water Trust expected to obtain from the first development, that is to say, from the Talla catchment area. The second development indicated above provided for the impounding of the Fruid Water (catchment area 5300 acres, average annual rainfall 55in) in a reservoir of some 1600 million gallons capacity at a top water level of approximately 1020ft O.D. The water from this reservoir was to be conveyed by a tunnel into Talla reservoir and was to pick up the waters of the Menzion Burn (catchment area 1400 acres, average annual rainfall 52in) *en route*. On investigating the flows of Fruid and Menzion during and immediately after the war years, however, it was found that by abstracting the water available between flows of 2½ and 27½ m.g.d. in the case of Fruid, and between 0·625 and 15·625 m.g.d. in the case of Menzion, and equalising the flows of the two streams in Talla reservoir, approximately 6 m.g.d. could be obtained over the three driest consecutive years without meantime constructing the reservoir. As this quantity was likely to prove sufficient for some twelve to fifteen years ahead, and as the then estimated cost, i.e. in 1947, of obtaining this water was only some £250,000 as against the £1,000,000 required for the development including the reservoir, the Corporation decided to restrict the development to the tunnel works with the necessary intakes on the two streams for the abstraction and diversion of the water. An Order under the provisions of the Water (Scotland) Act, 1946, authorising the carrying out of the scheme was obtained from the Secretary of State in January, 1949; and the work was let to contract in July, 1949, and commenced in August of the same year.

The Order referred to, it should be noted, limits the abstraction of water from the two streams to between the minimum and maximum flow limits indicated above. These minimum limits represent, in the case of Fruid, double the minimum dry weather flow of the stream, and in the case of Menzion rather less than double the dry weather flow. Subject to the natural flow of the two streams being sufficient for the purpose, the Order also requires the provision of flows of specified amounts and duration below the two intakes during each period of seven days between September 28th and November 30th in each year to facilitate the passage upstream of migratory fish.

The works comprise essentially intakes on the Fruid Water and Menzion Burn, the inner half of the river diversion and outlet tunnel of the future Fruid reservoir, and an aqueduct therefrom in tunnel to Talla reservoir. The total length of the tunnel is approximately 1¾ miles and for the greater part of this length it is in rock.

The intakes on the two streams are formed of weirs in mass concrete in which are incorporated fish passes for the passage of migratory fish, and also floating weirs to ensure the maximum permissible abstraction consistent with the maintenance of the minimum flow to the stream. In terms of the authorising Order, 25 m.g.d. may be abstracted from Fruid, and 15 m.g.d. from Menzion; orifices are incorporated in the intakes which limit the abstraction to these quantities. Sluice gates are also provided to allow the water level upstream of the intakes to be lowered for cleaning and maintenance, and to prevent debris as well as fish obtaining entry to the outlet orifices, screens are fitted immediately upstream of the intake weirs. Behind, i.e. downstream of the intakes, measuring weirs and recorders have been installed from which a continuous record will be obtained of the quantities of water being abstracted from the two streams.

The length of the future diversion tunnel which has been constructed meantime extends for a distance of approximately 140 yards, i.e. as far as the centre line of the future dam. This tunnel will ultimately have a finished diameter throughout of 12ft and, as indicated above, will be utilised when the reservoir on the Fruid is being constructed, for the diversion of the river and as the supply and compensation water outlet from the reservoir.

From the end of the diversion tunnel the aqueduct tunnel as far as Menzion has a finished size of 5ft wide by 6ft 3in high, and from Menzion to Talla of 6ft wide by 6ft 3in high. The length of tunnel from Fruid to Menzion is 4700ft and from Menzion to Talla 3315ft. The form of cross-section is the same throughout, i.e. vertical side walls with curved invert and semi-circular roof. Across the valley of the Menzion the aqueduct has been constructed in open-cut.

The gradient of the aqueduct tunnel is 1 in 3000 and that of the diversion tunnel 1 in 250. The water is conveyed, as previously indicated, first through a measuring chamber and then to the tunnel by means of a 36in diameter reinforced concrete pipe in the case of Fruid, and a 24in in that of Menzion.

In the soft, i.e. glacial drift, the tunnels are formed with precast reinforced concrete segments, but the greater part of the work is in rock (Greywacke) and this form of construction is confined to two short lengths at the entrances to the 12ft and 6ft tunnels. The diversion tunnel, where in rock, is lined throughout to a nominal thickness of 18in, and the aqueduct tunnel to a nominal thickness of 6in with, in each case, 1 : 2 : 4 concrete using ¾in crushed whinstone aggregate.

Tunnelling was carried out continuously on a shift system (the number of shifts worked per week being eleven), and except for short intervals, from four faces, i.e. simultaneously from both ends of the Talla-Menzion and the Menzion-Fruid tunnels. The driving crews averaged fourteen per heading; and the normal week's drive was 72ft per heading with maxima of 152ft in the Menzion-Talla heading and 136ft in the Fruid-Menzion heading. Both tunnels met without sensible error either of alignment or level.

Two rock drills were employed on each heading, the average number of holes drilled per round in the aqueduct tunnels being fifteen to seventeen by 6ft long. Using an average of about 50 lb of gelignite approximately 5ft 6in to 6ft of rock was drawn on each round. Mucking was carried out by "Eimco" rocker shovels loading into Jubilee skips and the haulage by electric locos in tunnel and diesel locos in the open. As the length of tunnel progressed from the headings it was necessary to install ventilating plant at the Talla and Menzion portals to clear the air after shot firing and to maintain a supply of fresh air at the working faces.

Steel arch rings of 4in by 3in and 5in by 4½in "I" section connected by corrugated steel laggings were used for the support of the roof where falls from the roof threatened to occur due to faulted rock. A total of 216 of these rings were required in the aqueduct tunnels and thirty-two in the diversion tunnel.

The sides and roof of the aqueduct tunnels were concreted in one continuous operation and the invert was placed later when all the other operations in the tunnel were finished. A fabricated steel shutter was used for the lining. The concrete was run into the tunnel in end-tipping skips and fed into a pneumatic placer from an elevating conveyor. The concrete was then blown into the shutter by compressed air through the pneumatic placer. The length of lining concreted in one operation was 40ft. On the average this was filled in five and a half hours and stripped after ten to twelve hours. One 40ft length was normally concreted each day, giving 200ft of lining concreted in a five-day week.

In the part of the diversion tunnel located in rock collapsible shuttering of dressed timber supported on tubular steel scaffolding was used. The concrete lining to the sides and invert was placed with a concrete pump situated at the tunnel portal and the roof was filled using the pneumatic placer.

The coarse aggregate for the concrete lining was originally obtained by crushing the Greywacke rock obtained from the tunnel excavation, but subsequently it was found necessary to obtain the aggregate from outside quarries.

Work commenced at the Talla end of the Talla-Menzion tunnel on November 7, 1949, and this tunnel was holed through on July 12, 1950. Work at the Fruid end of the tunnel commenced on December 28, 1949 and at the Menzion portal of the Fruid-Menzion tunnel on November 28, 1949. This tunnel was finally holed through on December 19, 1950. The average number of men employed on the contract during the progress of the tunnelling operations was 175.

The Fruid intake takes the form of a mass concrete weir with a cut-off wall averaging 7ft deep below the bed of the stream. The main weir was constructed in two sections. A coffer-dam was formed to divert the Fruid Water so that the first section of the weir could be concreted in the dry. The river was then rediverted through the sluice gate incorporated in this section and the remainder of the weir was then constructed.

The level of the invert of the aqueduct where it crosses the Menzion Valley is approximately 25ft below ground level and it was therefore necessary for special precautions to be taken to prevent the Menzion Burn flooding the open cutting across the Menzion Valley. A length of aqueduct was first constructed behind a sheet pile coffer dam and the burn was then diverted

over this section. When the aqueduct was completed the burn was rediverted to its original course.

The scheme has also involved the construction of new roads, one up the valley of the Menzion for a distance of fully a mile, and the other of shorter length alongside Talla reservoir. With the completion of this scheme the supply potential of the undertaking is increased from 33½ to 39½ m.g.d.

The works were designed and their construction supervised by the civil engineering staff of the Edinburgh Water Department under the direction of the city water engineer. The work has been carried out by contract by W. and J. R. Watson, Ltd.

Standard Class "4" 2-6-0 Locomotives

A PHOTOGRAPH reproduced on this page shows the first of the new 2–6–0 class "4" standard tender locomotives, twenty-five of which are now being built for British Railways at the Horwich and the Doncaster works. Five of the new engines are to be allocated to the Scottish Region, fifteen to the Southern Region, and five to the North-Eastern Region. The new locomotive, as in the case of the other standard engines, was designed and built under the direction of Mr. R. A. Riddles, the member for mechanical and electrical engineering of the Railway Executive. It follows very closely the other standard engines in service on British Railways, and many of its details are interchangeable with those of other locomotives.

The leading dimensions are as follows :—

Cylinders (2)	17½in dia. × 26in stroke
Wheels :	
Coupled diameter	5ft 3in
Pony truck diameter	3ft
Tender diameter	3ft 3½in
Wheelbase :	
Coupled	15ft 4in
Engine	24ft 1in
Engine and tender	46ft 11½in
Heating surface :	
Tubes	1,061 sq. ft
Firebox	131 sq ft
Total evaporative	1,192 sq ft
Superheater	254·3 sq ft
Grate area	23 sq ft
Boiler pressure	225 lb per sq in
Tractive effort	24,170 lb
Adhesion factor	4·59
Weight of engine in working order	59 tons 2 cwt
Weight of tender in working order	42 tons 3 cwt

The boiler barrel consists of two rings, the second being tapered, the outside diameters being 4ft 9⅛in at the front, and 5ft 3in at the firebox end. A drumhead smokebox tube plate has provision for twenty-four large flue tubes, 5⅛in outside diameter, and 154 small tubes, 1⅝in outside diameter, the length between tube plates being 10ft 10½in.

A slide valve regulator fitted into the dome is operated by an external pull rod connected to a transverse shaft which works through a stuffing-box on the second barrel plate. Boiler mountings, such as the manifold, safety valves, clack valves, &c., are as fitted to other standard British Railways locomotives with their controls operated in a similar manner.

The outside dimensions of the Belpaire firebox are 7ft 6in long and 4ft 6½in wide, with a $\frac{7}{16}$in thick steel wrapper plate and vertical $\frac{11}{16}$in thick throat plate. A copper inner firebox with $\frac{1}{2}$in thick wrapper plate and 1in thick tube plate is fitted.

The rocking grate is transversely split into two halves, each half consisting of three rocking sections, with fourteen renewable firebars in each section. Each half grate can be rocked separately from the footplate and for two different travels as on other British Railways engines, a short travel being used for agitating the fire while the engine is on the road. A two-hopper, self-emptying ashpan has butterfly doors operated by a hand lever from ground level, and its damper doors, fore and aft, are controlled separately by standard hand wheels and screw gear.

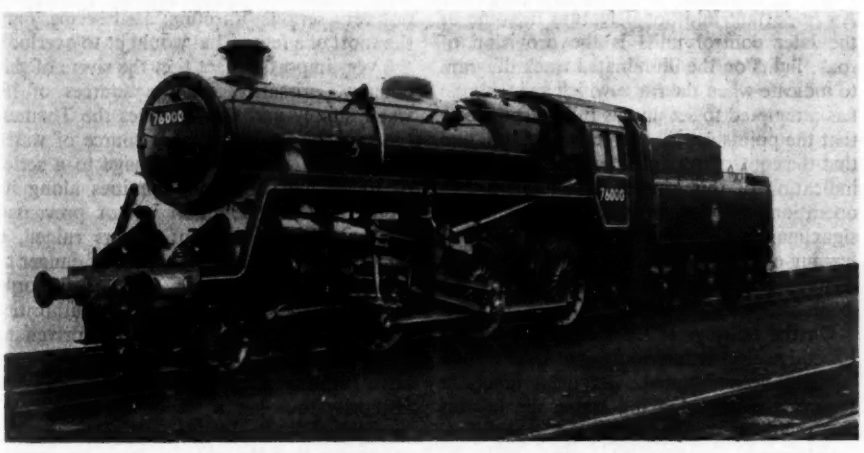
A self-cleaning, cylindrical smokebox is cradled by a fabricated saddle. The blast pipe has a standard plain circular cap, with a 4⅛in diameter nozzle incorporating the blower ring.

The main frames of 1⅛in thick plates are spaced 4ft 1⅛in apart, and are well braced horizontally and vertically by fabricated plate stays. Pin-jointed cross stays are attached to each of the axlebox guides, both the guides and axleboxes being fitted with manganese steel liners. The engine has plain bearings on all wheels, pressed-in white-metalled brasses in cast steel axleboxes for the coupled axles, and for the pony truck boxes, white-metalled bronze castings.

The pony truck, springs and brake gear are standard items, as also is the method of carrying the boiler hind end by brackets on the dragbox. As well as its normal duties, and supporting the boiler, the fabricated dragbox is designed also to carry the steam brake cylinder and brake shaft brackets.

Two linered, cast steel, outside cylinders are fitted with box pistons, each having two rings and a bronze spring-loaded slipper which carries the head clear of the cylinder barrel. The 10in diameter piston valves having a steam lap of 1⅛in and a lead of ⅛in, are operated in Walschaerts valve gear, the maximum travel in full forward gear (75 per cent cut-off) being 6⅛in.

The motion itself follows very closely that of the class "3" tank engines having the same valve events diagram, and many parts are used on both engines. As on all other British Railways standard locomotives to date, the lubrication of motion pins and reversing gear is by grease nipple and gun. Cylinder and valve chest lubrication is by atomised oil, delivered by mechanical lubricators. Standard steam-operated cylinder cocks are used and the cylinder covers are fitted with relief valves.

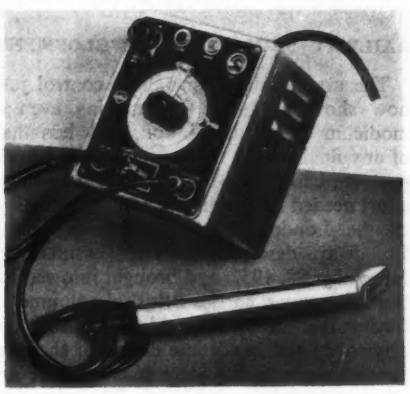


British Railways Standard Class "4" Locomotive

An Electronic Temperature Controller for Laboratory Use

OUR illustration shows an electronic temperature controller produced by the equipment division of Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. This simple laboratory instrument enables the temperature of water and oil baths and similar apparatus to be controlled to within fine limits, the response time being very rapid. It is suitable for use in connection with chemical analysis and polarographic, conductivity, viscosity and refractive index measurements.

The sensitive element in the new "E 7594" temperature controller consists of a temperature-sensitive resistor, designed for direct immersion in the fluid to be controlled. This resistor forms one arm of an a.c. bridge network. The output from this network is amplified and is used to control a phase-sensitive circuit operating a relay. Since the phase of the bridge output changes very rapidly at the point of balance, quick action of the relay is ensured. The relay in the instrument is of a single-pole, double-throw relay, which can switch up to 1A at 230V.



Electronic Temperature Controller

The instrument has a temperature range of 15 deg. to 75 deg. Cent. covered in three steps. A large dial allows the setting point to be precisely located and locked in position. Although the calibrated accuracy of the scale is ±1 deg. Cent., it is possible to control the temperature to within ±0·02 deg. Cent. about the working point. A four-position range switch is provided which alters the value of the resistor in the fixed or standard arm of the bridge circuit. The adjacent arm of the bridge contains the temperature-sensitive element, whilst the remaining two arms are provided by the potentiometer balance control. The fourth position of the range switch connects the bridge to a socket on the front panel of the instrument. This facility enables a precision external resistor to be connected into the bridge in place of the internally connected standard resistor. By keeping the external resistor at a constant temperature, a greater accuracy of control can be effected. Moreover, through the choice of suitable resistance values, the range of the instrument can be extended to cover any temperature between minus 50 deg. Cent. and plus 80 deg. Cent.

The temperature controller operates from 50 c/s, 110–120V or 200–250V supplies, the power consumption being 25W. The overall dimensions of the instrument, as illustrated, are : control unit, 6in by 7in by 6in ; probe unit, 10in by 1in by 1in, and the weight of the complete unit is 9 lb.

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RAILWAY SIGNALLING DEVELOPMENT

The art of railway signalling control just now shows no signs of reaching even a modicum of standardisation, still less that of any finality. In the sphere of concentrating such control, and of lessening the mental effort needed from signalmen, the installation of the London Transport line at Ealing Broadway, described in THE ENGINEER of November 28, 1952, and brought into service three days later, carries British developments further than ever before. In appraising the originality and handsome design of the new control machine, the steps by which the art of control have progressed from the first introduction of power signalling in this country, in 1898, are worth recalling. Then the electro-pneumatic system was installed on the Great Eastern Railway at Granary Junction, Bishopsgate, to speed point and signal operation, and to enable one man to control a larger area than would otherwise have been possible. Similar plants, using a British-designed power interlocking frame, were installed for the same reason at such large centres as Hull, Newcastle, Bolton and Glasgow Central. In all these early installations the signals themselves were lower-quadrant semaphores, and the underlying aim of each was rapidity of operation and concentration of control. Later came the addition of track circuiting, to reinforce the original advantages of power signalling by the safeguards of track locking of the levers, and to extend the control area beyond sighting distance from the signalbox, by the aid of illuminated track diagrams. But still the locking frame remained of the conventional type, the interlocking between levers being by mechanical means —a miniature version of the mechanism to be found in manually operated boxes. It was, indeed, not until 1929 that any departure was made from this practice.

The locking frame installed at North Kent East Junction, Southern Railway, in 1929, was conventional in appearance, but the lever interlocking was electric instead of mechanical. From this beginning developments in the art of electric interlocking have come rapidly. The growing intensity of traffic at many important centres led to a desire to improve regulation by concentrating control of a relatively large area in one place. To do this it was necessary to relieve signalmen of all but the more essential duties, and enable them to concentrate upon the work of regulating the flow of traffic without the distraction of having to walk up and down a long interlocking frame, or to pull heavy levers. Out of this expression of an ideal came the panel control machine, with non-interlocked thumb switches. The interlocking to safeguard against the setting up of conflicting routes was accomplished through the agency of relays, but although the control panel itself could be made very compact the number of relays and other control apparatus required was not conducive to much reduction in the cubic capacity of the newer signalboxes. Not only were small thumb switches used instead of levers, but the circuits were so designed that one switch could set up an entire route—sometimes involving a dozen or more pairs of points and several signals. These control panels have proved very successful in the handling of traffic, and it seems likely that their use will be greatly extended on British Railways. An important additional feature in some of the later control units is the provision of route lights on the illuminated track diagram to indicate when the route which a signalman has attempted to set up has fully responded ; that the points are all correctly lined up, and that the controlling signal has cleared. Some indication of this kind is a valuable aid in operations with an instrument on which a signalman may perform the physical act of turning a route switch, while the route itself, through some conflicting movement, is not available.

On the railways of the London Transport Executive electric interlocking of lever frames has not been adopted. At most junctions requiring an interlocking frame the layouts are relatively simple, and the mechanical interlocking mechanism can still be used with advantage. On the other hand, London Transport has developed a novel form of remote control, whereby the levers of a power interlocking frame are actuated by small air cylinders, electrically controlled from any desired distant point. The lever interlocking remains mechanical, and standard signalling circuits are used between the large contacts of the frame, and the ground apparatus. The remote control of the lever operation is carried out through the agency of lighter wiring and telephone type relays. Outlying junctions can thus be controlled from a central signalbox, and considerable economies in wiring effected ; light wiring only is needed to the remotely controlled subsidiary box, and standard signalling control and operating circuits confined to the vicinity of the outlying junction. In emergency a signalman can be sent to the outlying junction box, and the locking frame there operated by pulling the levers. In the new installation at Ealing Broadway a remotely controlled locking frame is again used, but this time controlled from a novel form of panel. To set up a route the signalman has to press no more than a single button. If the route is not available at the moment the controls are preselected and the route sets up automatically the moment all conflicting movements are clear. But no further action of any kind is needed from the man, and the push button requires no further actuation to restore conditions to normal after the train movement is completed. Indication of the state of any route is given by the display of different colours through the Perspex push button itself—red for normal, orange for a route preselected, but not set up, and green for a route that is set and the controlling signal cleared. By thus eliminating the need for any action after the train has passed London Transport has achieved yet another notable advance in the science of modern signalling control.

POLLUTION OF THE DERWENT

Some sympathy will be felt by many municipal engineers for Derby Corporation, which has just lost an appeal against an injunction against it, granted last April by Mr. Justice Harman, restraining it from polluting the River Derwent by the discharge of sewage effluent from its sewage works, the injunction to be suspended for two years. It may be thought because the action against the Corporation was brought by an angling association and a private individual interested solely in angling that the matter is not very serious, affecting, as it seems, only the sport of a few. That would be to overlook the very important fact that the rivers of this country, primarily, are the sources of its water supply and that, as does the Thames, the same river can act as a source of water supply and a means of drainage to a series of towns and other communities along its banks. Where pollution is not prevented not only is the sport of anglers ruined, a public amenity spoiled, a source of danger to public health created, and waterborne diseases conveyed to cattle, but authorities in need of water supply may be driven to look, expensively, elsewhere, for sources, as have Birmingham and Liverpool. A public authority thus has a responsibility to communities downstream (as well as to anglers) to ensure that the effluent from its sewage works has been adequately treated.

The Derby Corporation, in its appeal, did not deny that effluent from its sewage works was unsatisfactory. But the grounds upon which it based its appeal reveal its difficulty. It was submitted that the existing sewage works were at the time they were completed satisfactory and operated in accordance with the relevant Act ; but that owing to an increase of population over which the Corporation had no control and in the absence of any negligence on the part of the Corporation, the system now functioned so as to be a cause of nuisance. That, it was contended, was mere "nonfeasance" and the only remedy of anybody damaged was therefore by an application to the Minister of Local Government and Planning calling on him to compel the Corporation to enlarge its sewage system. Another contention was that since licences had to be obtained for building operations and the money required could only be borrowed with the consent of the Minister, no injunction should have been granted; and a still further one that no injunction ought ever to be granted by the Courts against a local authority in regard to sewage as an injunction could be held to be a means of bringing improper pressure to bear on the Minister in the exercise of his duties. The Master of the Rolls, in giving judgment, rejected those contentions and held that if a corporation in the exercise of any of its functions caused a private nuisance to any person, it was liable to be sued in the Courts like any other subject unless it could rely upon some statute expressly providing a defence against such an action. There was no reason why an injunction should not have been applied in the case before him.

There are a number of comments that might be made about the contentions of the Corporation. But as it is possible that leave to appeal may be granted by the House of Lords the case appears still to be *sub judice*. However, it can be remarked—it is the cause for the qualified expression of sympathy with which this article opened—that the present is a difficult time for local authorities, the majority of which, and no doubt Derby Corporation amongst that majority, take their duties very seriously and are very conscious of their responsibilities. For, as the defence of the Corporation reveals, engineers to local authorities to-day may find themselves handicapped in carrying out works that they regard as urgent by the necessity of obtaining licences for building and approval for the borrowing of money. They have, in consequence, in carrying out their duties to pick and choose to the best of their ability amongst jobs of almost equal urgency. Nor, so far as they are responsible for sewage works, have their difficulties been eased by the provision in the pre-war Public Health (Drainage of Trade Premises) Act of 1937, laying public authorities under an obligation to receive and dispose of industrial effluents in their districts. For the operation of that Act, beneficial though it has in general proved, has created special problems in some disposal works and created them just at a time when restrictions on capital expenditure make it difficult to expand or develop sewage works to receive and treat such effluents and at a time when in many areas home building and extensions to water supply schemes are by themselves tending to overload the works. It is both a fortunate and an unfortunate fact that within restricted limits rivers have a high power of purifying themselves rapidly of pollution. It is fortunate in that, at first, an overloaded sewage works occasionally discharging limited amounts of insufficiently treated effluent will do very little damage. But unfortunately, there may be reason to suspect that sometimes authorities—and even the Ministry as well—come to regard the extension of a sewage works when recommended by an engineer as, in consequence, not an urgent task, but one that can be put off until a more convenient season. The case involving Derby Corporation is doing good by bringing to light the difficulties under which that Corporation and, no doubt, many another authority are labouring, under present financial and licensing difficulties, and the fact that the failure of an authority fully to rise to its responsibilities may not be wholly within its own power to correct.

Obituary

P. E. ERIKSON

We regret to record that Mr. P. E. Erikson, who was prominent as a telephone engineer and a member of the International Standard Electric Corporation, died suddenly at the age of seventy-two on Sunday, December 7th, at his home at Malmo, Sweden.

Mr. Erikson received his degree in electrical engineering from the Royal Institute of Technology, Stockholm in 1903, and joined the Western Electric Company, New York, as a shop student the same year. On being assigned to the engineering department, he was engaged on the early development of loading coils and balanced toll cables. In 1909 he was appointed transmission engineer for Europe, with headquarters in London, and was in charge of the construction of the London–Birmingham cable, the first loaded long-distance cable installed in Europe. During 1918 he carried out the reconstruction of the Rio de Janeiro–San Paulo toll line, the first of its kind in Brazil to be equipped with repeaters and loaded toll entrances cables.

Later, as assistant European chief engineer of the International Western Electric Company, he had charge of the design of toll transmission systems which were being introduced into various European countries after the first world war. In 1928, he was made assistant vice-president of the International Standard Electric Corporation and European chief engineer in 1930. From 1924 to 1929 Mr. Erikson was actively engaged on C.C.I.F. work under the direction of the late Sir Frank Gill, and from 1929 onwards he was a delegate for the I.T. and T. Operating Companies at the meetings of that body.

In 1938 he became a member of the board of directors of A.B. Standard Radiofabrik, Stockholm, a subsidiary of the I.T. and T. Corporation. Two years later he was transferred to Sweden and acted as liaison officer between the International Standard Electric Corporation in New York and the Scandinavian companies, which were isolated by belligerent action from 1940 to 1945. After the war he was recalled, in 1946, to full-time service with London headquarters as technical adviser to the European commercial department. He retired from active service in September, 1950.

Mr. Erikson was a member of the Institution of Electrical Engineers, a Fellow of the American Institute of Electrical Engineers, and a member of "Svenska Teknologforeningen," Stockholm, Sweden. He was the author of numerous papers and articles and joint author with Mr. R. A. Mack of a paper entitled "Transmission Maintenance of Telephone Systems," read before the Institution of Electrical Engineers, London, on March 6, 1924—a paper which earned the award of the I.E.E. Fahie premium. He was also author of a paper entitled "The Present State of Long-Distance Cable Telephony in Europe," presented to the International Scientific and Technical Congress of Telephony and Telegraphy in commemoration of Volta, at Como, in September, 1927.

PROFESSOR J. S. S. BRAME

It is with regret that we record the death of Professor J. S. S. Brame, of 3, Vanbrugh Fields, Blackheath, S.E.3, which occurred last week on Wednesday, December 10th, at the age of eighty-one. John Samuel Strafford Brame was born in 1871 and was educated at Sir Thomas Rich's School, Gloucester, and the Royal College of Science, South Kensington. Upon the completion of his technical education he became a demonstrator at the Royal Naval College, Greenwich, where he continued to serve in various capacities until he retired in 1932. He was made an instructor at the College in 1910 and four years later became Professor of Chemistry, a position which he continued to hold until 1932. Professor Brame, who was awarded the C.B.E. in 1930, was the president of the Institution of Petroleum Technologists during the years 1921 to 1923 and chairman of the Standardisation Committee. He was also a Fellow of the Royal Institute of Chemistry and contributions from his pen appeared in the *Journals* of the Chemical Society, Society of Chemical Industry and the Institution of Petroleum Technologists. The Cantor and Howard lectures were delivered by him before the Royal Society of Arts and other publications of his include "Treatise on Fuel—Solid, Liquid and Gaseous," and "Service Chemistry."

Literature

Locomotive and Train Working in the Latter Part of the Nineteenth Century, Vol. III. By E. L. Ahrons. Edited by L. L. Asher. Cambridge: W. Heffer and Sons, Ltd. Price 15s.

Volume three of "Ahrons" deals with the Scottish lines, and covers that colourful period when Dugald Drummond was on the North British and later on the Caledonian ; when James Stirling was on the Glasgow and South-Western, and, above all, the times of the two "races," to Edinburgh in 1888, and to Aberdeen in 1895. Ahrons writes in his usual vivid style, but never better than when he has something apart from engineering or straightforward railway operation to discuss. His factual descriptions of locomotives and train services are valuable historically ; but it is when he reaches such items as the early adventures of the Great North of Scotland that he really touches the heights. "Its stopping trains," he writes, "could not even be dignified with the title 'slow.' They set the pace of a glacier, only the glacier would possibly have got there first. But one thing the Great North did thoroughly well—it charged 'express' fares for the privilege of a passage on its glaciers ; and these express fares were of an exceeding magnitude. . . . The mystery remains as to how the Aberdonians of that day were ever got to pay such fares for conveyance

in trains which averaged 12 to 15 m.p.h. Bang went the saxpences! Just think of it!"

Seeing that the articles dealing with the Highland Railway originally appeared as late as 1921 in *The Railway Magazine* series, one feels that Ahrons did less than justice to the work of David Jones. The various designs of 4-4-0 passenger engines turned out between 1874 and 1896 were splendid examples of constructional practice, and among the most powerful running in Great Britain, and the fact that in this volume they are treated in little more than "catalogue" style suggests that for once Ahrons had not that first-hand knowledge of their work that enabled him to write so entertainingly elsewhere.

The illustrations, particularly of North British and Caledonian locomotives, are among the finest we have seen. Many are unusual, and they are beautifully reproduced. In the case of the Highland, with choice limited by space to eight subjects, it seems a pity that no less than three of those chosen should depict the odd varieties of tank engine running on the line, as these were insignificant both in number and in the locomotive practice of the railway as a whole.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

RADIOGRAPHIC INSPECTION

SIR,—In his article on "The Economic Aspects of Radiographic Inspection," in your issue of November 14th, Dr. Pullin points out disadvantages in the use of fluoroscopy as a substitute for radiography, except where only gross defects need be detected. It has been found, however, that substantial economies can be made by using fluoroscopy as a preliminary to radiographic inspection. Castings with gross defects can quickly be eliminated and the number to be radiographed considerably reduced with a consequent saving in time, films and processing costs.

By using an ultra-fine focus unit (0·2mm), which makes possible direct enlargement of the image, even finer defects can be detected. If, however, defects are missed by the operator the fault will be picked up later in the radiograph, because he is not passing specimens as perfect but as good enough to merit radiography.

I would also like to point out that a well-designed fluoroscopic set allows castings to be rotated mechanically by remote control and gives the operator a three-dimensional view of the specimen. A daily check on the dose received can easily be carried out if the operator carries a personal dosimeter, and this will give an immediate warning of any defect in protection. Cracks in the protective lead glass would, of course, be clearly visible and could be detected at once.

E. W. KOWOL

London, December 9th.

LOCOMOTIVE PERFORMANCE

SIR,—In reply to a point raised by Mr. E. B. Parker (page 764), I have to say that the G.E.R. performance in question was recorded in 1911. The locomotive concerned (No. 1809) was built in 1910, and I must add that its Belpaire firebox did, in fact, have a sloping grate with its rear end above the rear axle. The ratio of firebox heating surface to grate area was 5 : 4, which is about the average for fireboxes with sloping grates, whereas a firebox with a horizontal grate below the level of the driving axles usually has a higher ratio; in the L.N.W.R. "George," for example, it was 7 : 35.

W. A. TUPLIN

Sheffield, December 6th.

The Air and the Future*

By AIR COMMODORE F. R. BANKS, C.B., O.B.E., M.I.Mech.E., F.R.Ae.S., F.Inst.Pet.

IN my first address and a subsequent lecture I attempted to give you some idea of the historical development of the aviation engine; and I indicated the principal technical advances, such as supercharging together with the use of improved fuel, which determined our further progress and success in building engines and aircraft of outstanding performance in the last war—to the Whittle jet propulsion gas turbine; which was hardly a step, but a large jump that landed us into a completely new realm of aerodynamics, both in regard to the engine and the aircraft. The turbo-jet has, in fact, altered all the parameters of aviation.

Prior to the advent of the aviation gas turbine, the aircraft designer was never long satisfied with the power available for his needs; but when the turbo-jet arrived and so quickly established itself he was, temporarily, faced with more power than he could effectively use.

In the first place, the high power available from the gas turbine could not be used effectively with the conventional airframe because of the rise in "drag" or resistance of the aircraft to the air. This prevented the machine from going faster, regardless of the power used, due to "shock wave" forming on the aircraft surfaces in regions of high induced velocity.

These Mach number limitations were already with us in piston-engined aircraft, such as the "Spitfire" and the "Typhoon," before the advent of the gas turbine.

Aerodynamic improvements have now taken us up to the so-called sound barrier (Mach No. 1); and some experimental and research machines, notably the Douglas "Skyrocket," have exceeded the speed of sound by a good margin, i.e. have flown at over 1200 m.p.h. at an altitude of 79,500ft. I cannot envisage rapid development of supersonic aircraft except for special and urgent military requirements.

To-day, the guided weapon is being intensively developed for defensive and offensive purposes, thanks to the advances made in electronics and radar, &c. These developments may eventually eliminate the piloted fighter and, over a somewhat longer period, render the conventional bomber obsolete.

The piloted fighter will probably disappear within ten years (in favour of the guided weapon), and the orthodox bomber in fifteen or twenty years.

Since more effort has been put into the development of the turbo-jet, due to its military application, it is natural that this engine type is the more generally used; and with the success of the "Comet" in scheduled airline service, it would appear that the turbo-jet is also justifying itself as a prime mover of civil aviation.

In my opinion, jet propulsion, which also includes the ducted fan and the by-pass varieties, is the ultimate; and while the propeller turbine also has a rightful place, it will not usurp that of the turbo-jet.

The propeller turbine has the potential advantages of improved take-off thrust and better fuel consumption, although the advances made in recent years in the higher thrust-weight ratio of the turbo-jet, together with the relatively large improvement (15–20 per cent) in its fuel consumption, have closed the gap somewhat between the two engine types; and if the promise of the ducted fan or the by-pass engine is fulfilled, a further substantial improvement in fuel consumption can be expected. But there are still improvements to come from the propeller turbine.

While the propeller turbine offers more economical operation than any of the jet propulsion varieties, particularly at subsonic flight speeds (and I do not envisage supersonic passenger aircraft for many years), there are considerable problems to be overcome in connection with the development of the propeller for engines of 4000–5000 s.h.p. and upwards. Propellers are not yet trouble-free, even on the large piston engine of 3000–3500 b.h.p.

Propeller turbine aircraft may eventually be designed to fly as fast as their jet propulsion equivalents, in the high subsonic speed range, but I have a "hunch"—if I may use the word—that the preference for the relatively simple and less complex turbo-jet will be so strong that the further development of the former might be somewhat restricted and most of the available effort concentrated upon the jet.

It is a tribute to the ability of the engine constructors of this country that the present-day turbo-jet has proved itself sufficiently reliable for a first-class aircraft constructor and a major airline company to build and to operate a jet machine in scheduled service in only eleven years after the first flight of a jet-propelled aircraft—with a war intervening.

A good feature of gas turbines generally is that, once they are ready for the aircraft, they are fairly easily installed and give rise to fewer delays in subsequent flight tests, and in getting them into actual service, than the piston engine. This point was borne out at the recent S.B.A.C. display at Farnborough, when three or four prototypes had only done their first flights a few weeks before being demonstrated publicly.

You will have heard queried, and criticised, the effort which has been put into the development of the axial compressor type turbo-jet, as distinct from the apparent lack of interest in the centrifugal compressor.

The original Whittle engine had the latter type of compressor, and a very simple and attractive engine it was. But, fortunately or unfortunately, whichever way you care to look at it, aviation engineering, above all other branches of engineering art and science, is never static; and it was inevitable that engines offering greater power and improved fuel economy would almost immediately be demanded.

Since, by virtue of its working principle, the outside diameter of the centrifugal compressor is larger than its air inlet, and because it is not practicable to add more than one extra stage (making two stages in all) due to the serious loss in efficiency in the cramped bends between the stages, it will be apparent that the possibilities of developing further the centrifugal type turbo-jet had limitations.

I am not suggesting that this engine is incapable of improvement—any engine can always be bettered if the necessary effort is forthcoming; but it is purely a question of degree, which compares unfavourably with the much greater intrinsic improvement in overall performance offered by the axial compressor.

The air inlet of the axial compressor, because the air is not turned radially in its course (as in the centrifugal type) largely determines the overall diameter of the engine. The axial is, however, somewhat longer than the centrifugal, due to the fact that it has a greater number of work stages than the latter.

Put simply: for a given engine diameter the axial compressor takes in much more air than the centrifugal and, therefore, produces greater thrust per square foot of frontal area. Further, the efficiency of the axial is better than that of the centrifugal; and this contributes to improved fuel consumption, since less power is needed to drive the axial than the centrifugal for a given pressure ratio and air consumption. The higher pressure ratios, practical with the axial, also give superior specific thrust—up to a maximum ratio of about 8 : 1.

In specific terms, the thrust per square foot of frontal area of a centrifugal engine is between 400 lb and 460 lb, whereas that of an axial is now better than 1200 lb.

The specific weight (the weight per pound of thrust) was, at first, lower for the centrifugal than for the axial, later becoming similar for both types; but the axial type now has the lower specific weight.

The centrifugal is inherently more robust, the many blades of the axial rendering it more liable to damage by the entry of foreign bodies, which may either reduce compressor efficiency or be catastrophic to the whole blading.

Despite the greater production effort needed for the axial, its better performance fully justifies the extra cost; and nothing less than the best performance can be tolerated for the highly competitive military or civil aircraft.

* Presidential address to the Junior Institution of Engineers, delivered at the Royal Society of Arts on Friday, December 12, 1952. Abstracted.

Wilton Works Power Station

The power station described here is an important component of the Wilton works project which forms part of the post-war development programme of Imperial Chemical Industries, Ltd. Its functions are to produce steam and electricity for the various chemical plants in the Wilton works. The power station plant consists of two 265,000 lb per hour boilers delivering steam at 900 lb per square inch and 900 deg. Fah. to back-pressure turbo-alternators which exhaust into the factory steam mains at 250 lb per square inch. Steam from the 250 lb per square inch system is also delivered to pass-out turbo-alternators which provide steam for the factory mains at 20 lb per square inch and for feed water heating. The total installed generating capacity is 60·45MW.

EARLIER this month, at the invitation of Imperial Chemical Industries, Ltd., we visited the company's Wilton works to see the main power station which has been designed to supply steam and electricity for the various chemical plants that make up the Wilton project. In order that the functions and design of the power station may be better appreciated, we preface our description with a brief reference to the Wilton works itself.

The Wilton project was first formulated during the recent war to provide facilities for the company's large post-war development programme. In 1946 work was begun on the site at Wilton, which contains some 2000 acres of land suitable for industrial development. It lies between Redcar and Middlesbrough, being about 2 miles from the sea and from the River Tees. An additional area of 400 acres has been acquired, having direct frontage on the river and communicating with the main site by a corridor of land some 500ft wide. This land, which is mainly low lying, will be used for dumping waste products, including boiler ash, and may later be used for further industrial building.

In the six years since work was begun on the site, plant and services representing an expenditure of about £22,000,000 have been installed and the capital investment authorised up to the end of this year is about £39,000,000. So far nine chemical plants employing about 2000 men are in operation. A further labour force of about 1800 men is engaged in building and equipping the remainder of the plants and services to feed the existing installation. It is estimated that approximately one-tenth of the site area will have been built up by the end of 1954—a fact that gives some idea of the long-term development that may be envisaged at Wilton.

The Wilton works forms an industrial complex in which chemical plants are operated by four major divisions of Imperial Chemical Industries, Ltd., namely, Alkali Division, Billingham Division, Dyestuffs Division, and Plastics Division, many of the processes being closely interdependent. Thus the "Perspex" made by the Plastics Division uses acetone from Billingham, which, in turn, is derived from the olefine plant operated by the Billingham Division at Wilton. Another example of chemicals made from petroleum distillate is the ethylene glycol plant (Billingham, Wilton), which feeds the pilot plants at Wilton for making "Terylene" polyester fibres.

Most of the chemical plants use steam for heating fluids, driving turbines, facilitating separation by evaporation, and for space heating.

For turbines and for evaporation of organic liquids steam is distributed at a pressure of 250 lb per square inch. For evaporating water and for space heating it has been found convenient to use steam at a pressure of about 20 lb per square inch. At each of these conditions approximately 50 tons an hour of steam is required for the operation of plants now operating or being constructed. Wilton therefore provides a good example of the conditions that make it economic to generate steam at a higher pressure than is required for plant use and to produce electricity by letting down through turbines. After detailed examination it was decided to generate the steam at 900 lb per square inch, 900 deg. Fah.

The first stage of the power station comprises two Babcock and Wilcox high-head boilers, designed to supply steam at the turbines at 900 lb per square inch, 900 deg. Fah., each with a steaming capacity of 265,000 lb per hour. Normally, the boilers burn pulverised fuel, but they are designed for oil firing, if required (up to 100 per cent of M.C.R.), or for burning tail gas, a waste product from the works.

Steam is let down through either of two Metropolitan-Vickers back-pressure turbines to 250 lb per square inch, 640 deg. Fah. Each of these machines is similar to a high-pressure cylinder of a standard 60MW set. One carries the full steam output of two main boilers. The other will take the output of one boiler only. The big turbine drives a 17·5MW generator and the small one drives an 8·3MW generator.

After passing through these back-pressure or "primary" turbines some of the steam at 250 lb per square inch is distributed around the site. The remainder is let down through either of two pass-out or "secondary" turbines, also built by Metropolitan-Vickers Electrical Company, Ltd. Again, one turbine takes full load of two boilers, minus the steam distributed around the site, and the other takes half this amount. Most of the steam is passed out at 20 lb per square inch for plant use. To ensure flexibility in circumstances when the amount of steam used on the plants may not be quite sufficient to provide the plant electric load, additional stages are added after the pass-out connections, leading to condensers, adequate to handle up to about 25 per cent of the total steam fed into the sets. The two secondary turbines drive generators of 23·5MW and 11·35MW respectively.

The accompanying plan of the power station (Fig. 1) shows the plant layout and the steam pipework is shown in Fig. 4. A general impression of the supply services is given by Fig. 2, which shows the pipework for steam, condensate, gas, air and chemicals, at "Piccadilly Circus," where two main avenues intersect. Electric cables are run on the surface of the trenches and in the trough skirting the circus.

For greater operating flexibility a link has been provided with the North Eastern Electricity Board system with a capacity of 30MVA. It is operated at a pressure of 66kV transformed to 11kV and fed into the Wilton power station busbars. This link is used either to export surplus power to the national grid or to import power to the site, and its existence eliminates the need for stand-by generator capacity. Power is generated at 11kV and distributed round the site by ring mains and radial feeders at this pressure. It is transformed down to 3·3kV for the bigger drives or 415V for smaller motors and lighting purposes.

The whole power station is so planned that it can be extended to provide steam and electricity

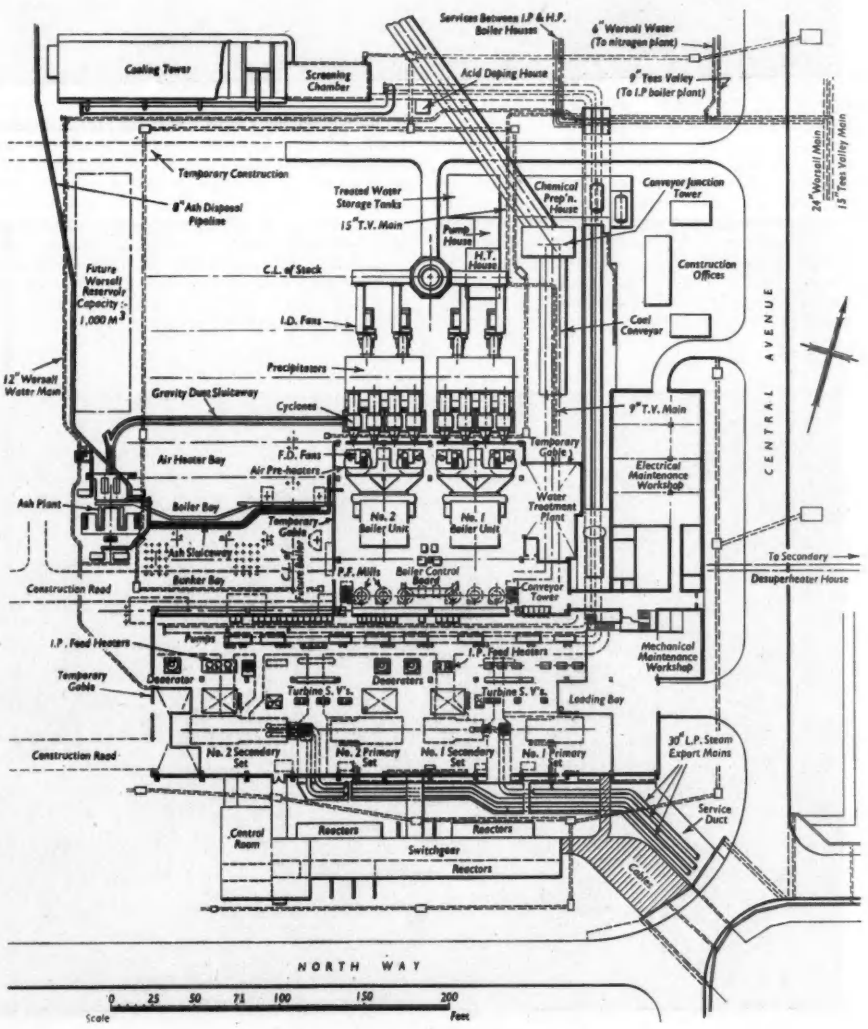

Fig. 1—Plan of Wilton Works Power Station

WILTON WORKS POWER STATION

Fig. 2—" Piccadilly Circus," showing Service Pipework

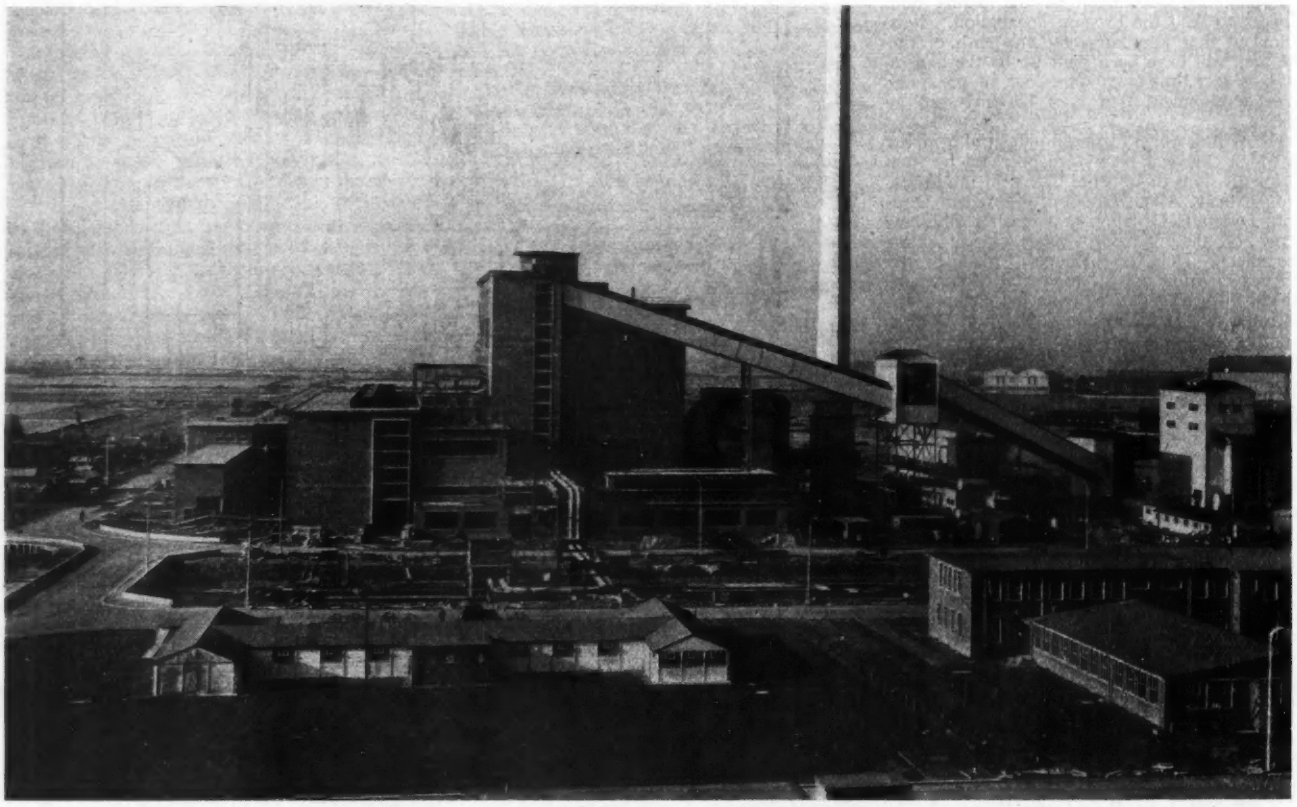

Fig. 3—Wilton Works Power Station Viewed from the East

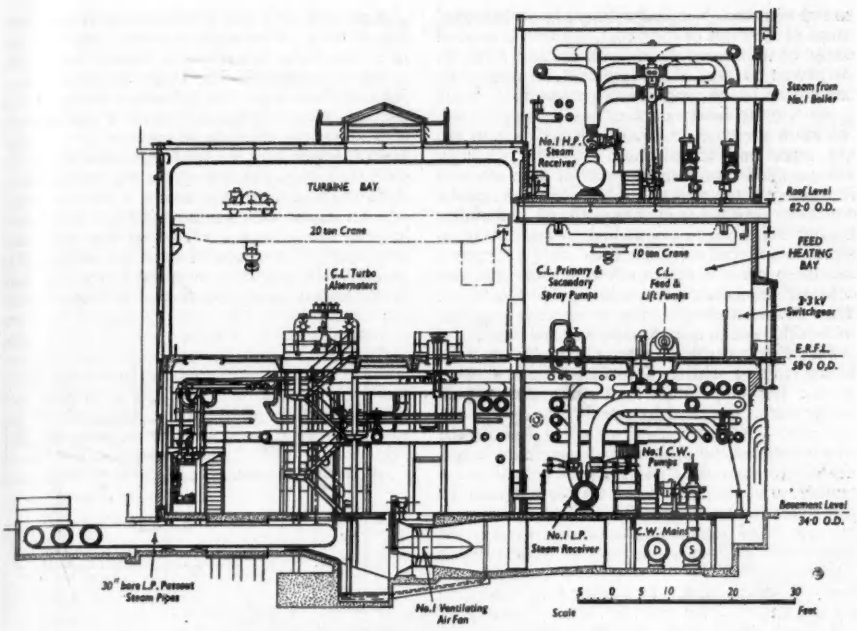

Fig. 4—Cross Section Showing Steam Pipework

for additional plants which may be constructed on the Wilton site. At present plans are in hand to install a third high-pressure boiler, of similar capacity and design to the two existing ones. When completed, this boiler will provide enough steam to feed all the turbines now installed in the power station. The maximum generating capacity will then be about 60MW.

In addition to the main high-pressure boilers, two oil-fired boilers, each of 132,000 lb per hour capacity, generating steam at 250 lb per square inch, 640 deg. Fah., are installed. They were put in initially to provide steam on the site before the main boilers could be completed and are now used as stand-by to the main boilers.

In Fig. 3 we reproduce a view of the power station from the east. From left to right the main building houses the main switch room, the turbine and feed heating bays, with the high-pressure steam piping and manifolds on the roof, the coal bunker bay with the lift tower in front, and then the boiler bay, cyclones and electrostatic precipitators. The photograph also shows the chimney, and the cooling towers, in the background, can just be discerned under the coal conveyor. On the extreme right is the original 250 lb per square inch boiler plant referred to in the previous paragraph.

Boiler Plant

The two high-pressure high-head boilers, one of which is illustrated in Fig. 5, have water-cooled furnaces, the tubes being covered by Bailey blocks.

Firing is by six 12in circular burners disposed horizontally in the front wall of the furnace and arranged for firing by pulverised fuel with three "E" mills per boiler. The burners are also suitable for alternative oil firing for lighting-up purposes or for load carrying at times of light load. These atomisers are of the Y-jet type, in which the oil is atomised by high-velocity steam jet. Gas rings are also provided around the burners for burning "tail" gases, which are waste products from the Wilton works.

The main drum is fitted with "Cyclone" steam separators and scrubbers. The superheater is of continuous loop design and surface type attemperators are provided between primary and secondary stages, for control of final steam temperature. Gas by-passing arrangements are also provided for further adjustment. The economiser is a multi-loop equipment, in two sections, each of three banks. The air heaters are regenerative, of the Howden-Ljungstrom rotary design.

For control of the steam conditions there are three primary desuperheaters and reducers each capable of desuperheating 120 tonnes per hour of steam at 900 lb per square inch and 900 deg. Fah. to 253 lb per square inch and 640 deg. Fah. There are also two i.p. export steam desuperheaters rated for 30/60 tonnes per hour to control i.p. export steam to 640 deg. Fah.

Fly-ash is dealt with by four Buell dust collector units each comprising four high-efficiency cyclones fitted at the air heater outlet. A Sturtevant electrostatic precipitator is also provided for each boiler.

There are nineteen sootblower units per boiler, of which fifteen, mounted in the furnace and superheaters, are Babcock single-nozzle retractable units. The remaining four, which are in the air heater, are of Babcock-Howden fixed units. Automatic control, using Babcock-B.T.H. electrically operated equipment, is provided to give full sequence control, or to omit any predetermined blower from the sequence, or to operate any individual blower. The sequence is also interrupted and an alarm sounded, if any blower head fails to complete its operation in a given time.

There are two Howden i.d. fans rated at 78,000 cubic feet per minute, two f.d. fans rated at 50,500 cubic feet per minute, and three primary air fans rated at 13,400 cubic feet per minute, per boiler. To make use of warm air above the boilers, the f.d. fans are installed just below boiler-house roof level and a glass partition acts as a baffle to exclude cooler air.

Coal and Ash Plant

The Babcock and Wilcox coal and ash-handling plant is designed to serve future boilers as well as the two present ones. Coal is received on site in railway wagons for unloading on a side-discharge wagon tippler, which weighs the coal and deposits it into an underground hopper. Thence the coal is delivered by a vibratory feeder to No. 1 belt conveyor, which elevates the coal and transfers it over end to No. 2 belt conveyor, which conveys it to the crusher house. There the coal is chuted to the "Flextooth" crusher (or by-passed if crushing is not desired). Before crushing, tramp iron is removed from the coal stream by a magnet suspended over No. 2 conveyor, or by the magnetic head pulley on the same conveyor. From the crusher, or by-pass, coal passes over a Niagara screen to remove non-magnetic rubbish and then to No. 3 belt conveyor, which is fitted with a Blake-Denison belt weigher, recording the amount of coal passing and delivering over-end to No. 3A belt conveyor. This conveyor transfers to No. 4 belt conveyor which rises into the boiler-house, where the coal is received by No. 5 belt conveyor. From this it is delivered to No. 6 belt conveyor (shuttle), which is mounted on a travelling carriage, to allow the coal to be deposited in any of the bunkers in the boiler-house. To limit the emission of dust, a dust extraction plant is installed in the tippler house.

The ash is collected in refractory hoppers under the furnaces and at intervals is fed by high-pressure water jets into a "Hydrojet" sluiceway along which it is conveyed and discharged through one of duplicate ash crushers into a sump, where further water is added as necessary. The ash and water mixture is pumped from this sump by two "Hydroseal" ash pumps in tandem, to a disposal area approximately 2 miles from the boiler-house.

Dust is collected from grit collector and precipitator hoppers by a "Hydrovac" system, and is discharged through feeder ejectors into the ash sump via the sluiceways, from whence it is pumped to the disposal area along with the ash.

High-pressure water to the sluicing jets, feeder ejectors, and for sealing the ash pumps, is provided by a centrifugal pump. Pressure-operated mercury switches trip the ash pumps if the sealing

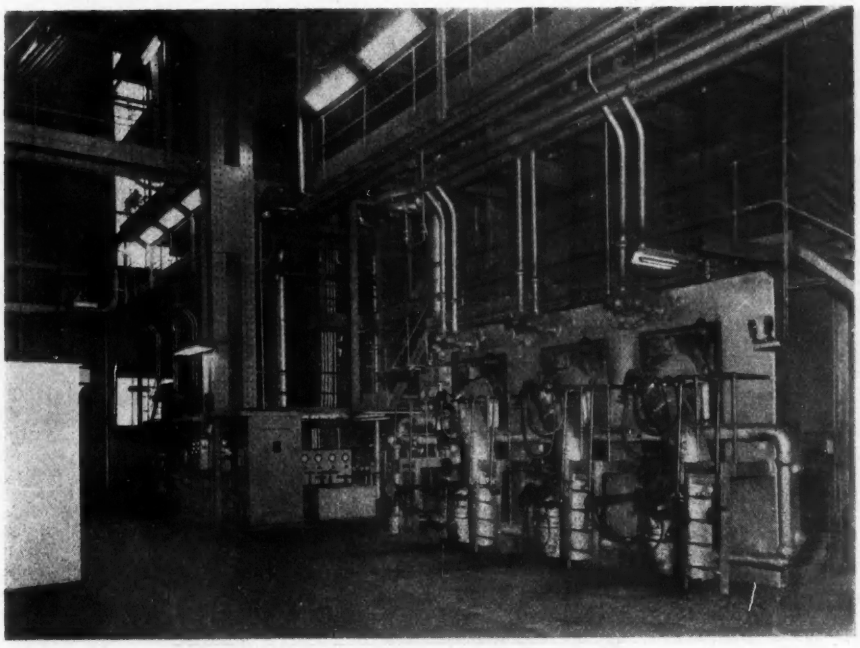

Fig. 5—H.P. Boiler Firing Floor and Soot Blower Cubicles

water supply should fail. Both the h.p. centrifugal pumps and the "Hydroseal" ash pumps are duplicated for standby service.

Boiler Control

Automatic control equipment for the boilers is centralised in switchboard panels, one for each boiler, made by Bailey Meters and Controls, Ltd. The control equipment is primarily operated by the master controllers of which in this instance there are two per boiler, one a master pressure controller and the other a master flow controller, so that the boiler can be controlled either by pressure, which would take care of alterations in load, or by flow, when the output of the boiler would be maintained at a constant figure.

Either of the above controllers operating through standardising relays can give proporportional plus integral control to the whole of the equipment. Fuel control is effected by changes in air loading pressure as sent out by either master controller through a "B41 CC" mill ratio relay through individual primary-air-flow reset transmitters "B41 AC," through a further standardising relay on to the individual primary air selector valves, and so on to the Bailey "A748" control drives, each operating their respective primary air dampers.

The effect of varying the amount of primary air to a type "E" mill is to ensure that the respective feeder controllers on each mill establishes the correct feeder motor speed to maintain the level of coal in the mill. These "B41 X" feeder controllers are actually part of the mill equipment. Thus a change in loading pressure from the master pressure controllers will affect the opening of the primary air damper and consequently the amount of coal fed to the boilers.

The object of the three "B41 AC" primary-air-flow reset transmitters mentioned above is to ensure that a correct relationship is maintained between the loading pressure received and the amount of air fed to the mill. The object of the "B41 CC" mill ratio relay controller is to permit the operation of the plant with either one, two or three mills.

The outputs of the f.d. fans and i.d. fans are vane controlled. In each case the vanes are controlled from the master loading pressure through an averaging relay, the correction for any deviation from the furnace pressure control point being effected by the furnace draught controller operating through a standardising relay and then to chamber "C" of the averaging relay.

Standardising relays for both the induced draught and forced draught are mounted horizontal with the spring adjustment knob extended through the front of the panel. With this control either of the forced or induced draught fans can be biased to keep the equipment on automatic control whilst carrying out soot blowing.

Among the subsidiary controllers fitted outside the main pressure or flow-controlled system are the three mill temperature controllers. They are gas-filled thermometers with a bulb inserted in the top of the mill and a bourdon helix in the controller operating a proportional controller, the loading pressure from which passes through a separate selector valve (in each case) and on to the three control drives operating the hot and cold air dampers at the primary air fan inlets. This device maintains the temperature at the mill outlet within a reasonably narrow band.

For the control of steam temperature, the boiler is fitted with two surface type attemperators: the temperature at the secondary superheater outlet is varied by opening or closing the butterfly valve, permitting more or less of the steam between the primary and secondary superheaters to pass over the surfaces at saturation temperature, the heat being transferred back to the water in the drum. This effect is achieved by means of resistance thermometers inserted in the two secondary superheater outlets which operate "WS 35F" electronic temperature recorder controllers. In addition to recording on the chart of the recorder, these instruments are fitted with a proportional controller which sends out a loading pressure to the respective standardising relay and on through the respective selector valves to the control drives mounted on the body of each attemperator to operate the butterfly valve. Thus this control is a proportional plus integral control and maintains the temperature within very close limits.

Steam Turbo-Alternators

A general view of the turbine bay is reproduced in Fig. 6, and the layout is given in the plan of the power station (Fig. 1). No. 1 primary set has a capacity of 8·3MW, No. 2 primary 17·5MW, No. 1 secondary 11·35MW, and No. 2 secondary 23·3MW, thus giving a total generating capacity of 60·45MW. The steam ratings of the sets are given in Table I, and the steam and feed-heating arrangements are shown diagramatically in Fig. 7.

The two primary machines are similar in design and provision has been made for the output of No. 1 primary to be increased at some future date to 17,500kW by reblading the turbine, should the load conditions warrant this course. Steam is supplied to the two primary turbines at 900 lb per square inch, 900 deg. Fah., and they exhaust into a steam main at 253 lb per square inch. This exhaust steam, supplemented by steam from low-pressure boilers is admitted to the two secondary turbines and is also used for process work. The primary turbines, which run at 3000 r.p.m., are single-cylinder units containing eleven impulse stages. The casings are of ½ per cent molybdenum cast steel, the shaft and discs being forged solid in one piece. Each turbine has twin steam chests mounted one on either side of the cylinder, each chest housing one governor valve and one emergency stop valve, the valves of each set operating in parallel. In addition to speed governing gear, back-pressure load pay-off gear is fitted to each

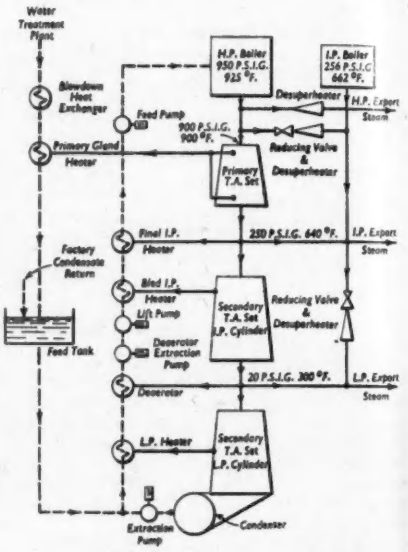

Fig. 7—Steam and Feed Heating Diagram

turbine in order progressively to reduce the governor valve opening and thus the steam admission as the pressure in the exhaust steam range increases, the control being effected through the medium of a bellows-operated relay valve.

No. 1 secondary turbine set is a 3000 r.p.m., single-cylinder, pass-out and condensing unit. It consists of a velocity compounded stage and fifteen single impulse stages. Steam is passed out at 20 lb per square inch gauge for process work

Table I—*Steam Turbine Ratings*

Turbine	Stop valve		Inlet steam quantity	Pressure at exhaust or pass out
	Pressure	Temperature		
	Lb/in²	Deg. Fah.	Tonnes/hr	Lb/in²
No. 1 primary ...	900	900	120	253
No. 1 secondary ...	247	640	70–90	20
No. 2 primary ...	900	900	240	253
No. 2 secondary ...	247	640	140–180	20

after the seventh stage, the pass-out pressure being under the control of a sliding disc valve automatically regulating the admission of steam to the low-pressure stages of the turbine. The admission of steam to this turbine is under the control of a vertical governor regulating steam admission to four nozzle groups, each controlled by a separate governor valve, and provision is made to vary at will the sequence of opening of these valves in order to secure high efficiency.

This set is provided with a Metrovick central flow single shell condenser, which has a cooling surface of 9000 square feet and is capable of passing 30/40 tonnes per hour to condensate at 28·5in Hg vacuum at turbine exhaust. The feed heating system for this unit consists of one low-pressure heater and two high-pressure heaters, all of Metropolitan-Vickers manufacture, handling 132 tonnes per hour and providing a final feed temperature of 394 deg. Fah. A Hick Hargreaves deaerator is incorporated in the feed system. A Metropolitan-Vickers gland heater is also provided and utilises gland leakage steam from the No. 1 primary turbine.

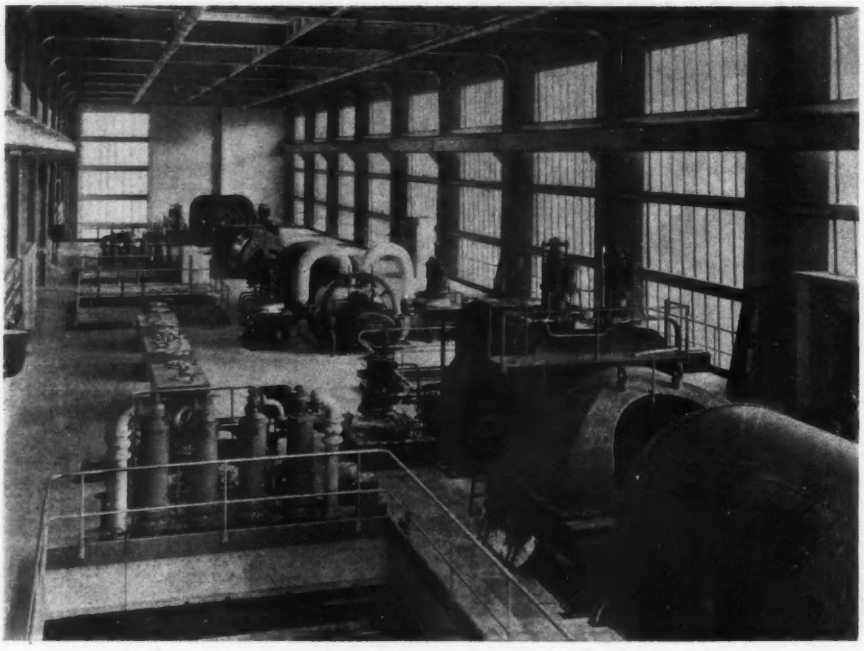

Fig. 6—Turbine Bay

No. 2 secondary turbine set is a 3000 r.p.m., two-cylinder, pass-out and condensing unit, the steam chest being formed integral with the top half high-pressure casing. The high-pressure cylinder houses twelve single impulse stages and the low-pressure cylinder eight single impulse stages. Steam is withdrawn for process work between the two cylinders at a pressure of 20 lb per square inch, the pressure being automatically controlled by two control valves, operating in parallel, which regulate the admission of steam to the low-pressure cylinder.

The condenser for this unit is an M-V central-flow, single-shell surface condenser with a cooling surface of 18,000 square feet, capable of handling steam to condensate at a rate of 60 tonnes per hour at 28·5in Hg vacuum. The regenerative feed heating system for this set consists of one low-pressure and two high-pressure M-V heaters. Incorporated in the system is also a Hick Hargreaves deaerator. The system provides a final feed temperature of 394 deg. Fah. and can handle 264 tonnes per hour. Two gland steam heaters are fitted to utilise gland steam from No. 2 primary set and No. 2 secondary unit respectively.

All the alternators are of orthodox M-V design and manufacture, and are wound for three-phase, 50 c/s at 11·5kV. Each machine is provided with its own air cooling system.

The feed, lift and circulating water pumps are of Mather and Platt manufacture, the main particulars being as given in Table II :

TABLE II—*Main Particulars of Pumps*

Duty	No. and type	Delivery	Temperature	Pressure
		Lb/hr	Deg. Fah.	Lb/in²
Lift	3 electric	300,000	242	375
Lift	1 steam	450,000	242	375
Feed ...	3 electric	300,000	392	1205
Feed ...	1 steam	300,000	392	1205
C.W. ...	2, No. 1 secondary set	7,000 gallons/min. together, 4,500 gallons/min. singly		
C.W. ...	2, No. 2 secondary set	14,000 gallons/min. together, 9,200 gallons/min. singly		
Aux. C.W.	2	2,400 gallons/min. each		

The circulating water is handled by induced draught cooling towers designed and supplied by Film Cooling Towers (1925), Ltd. As illustrated in Fig. 8 the towers are sectionalised so that one or more sections can be taken out of service, as required. The total capacity of the installation is 4200 cubic metres per hour and the towers are designed to cool to within 5 deg. Cent. of wet bulb temperature.

Operational control of the power station is centralised in a main control room, a photograph of which is reproduced in Fig. 9. The operator seated at the control desk has two main tasks : first, to ensure that steam is made available, by altering the governor setting, to meet the demands as they arise, and, secondly, to make the corresponding adjustments on the electrical side (which is in parallel with the public supply system) by tap changing. These operations are performed manually and the control knobs can be seen on the desk in front of the operator. The upright panels forming the perimeter of the desk, house indicating instruments and rectangular visual alarm indicators. The Reyrolle flush wall-mounted panels along the right of the control room relate to the electrical circuits. To the left of these panels is a " steam gauge and summation metering panel " containing indicating and integrating meters which give the control engineer all the information he may require about steam conditions and demand. For convenience the main dials indicating the l.p. and i.p. export steam pressures are duplicated on the control desk. The control engineer is in telephonic communication with key points in the power station and with electrical mains maintenance staffs throughout the works ; the works substations are generally unattended.

Electrical Equipment

As already indicated, the four alternators run in parallel with the North Eastern Electricity Board's system via two 66kV feeders. Each feeder has a capacity of 30MVA and has two 15MVA, 66/11·5kV Parsons transformers with on-load tap changing gear. The main switchgear is Reyrolle " A 3 T," 750MVA, oil-filled, double-busbar gear. It has two sections each connected to two alternators and to one of the Board's feeders with a busbar reactor between sections. Outgoing feeders to the plant are taken from each section. Future extensions can be made to this system to include two further sections of up to 40MW capacity each, after which it is probable that a separate system will be adopted.

The station earth comprises twelve 12ft and four 8ft copper rods and the alternator neutrals can be connected to them by Reyrolle type " C " switchgear via a Metropolitan-Vickers 1500A liquid resistor.

The station auxiliary supplies are taken from two 5MVA, 11·5/3·3kV Parsons transformers, one from each section of the main switchgear. These transformers are connected to English Electric 3·3kV, 150MVA airbreak " O.B.33 " double-busbar switchgear. Power and lighting supplies for the turbine house and the boiler-house are obtained via two 500kVA and three 1000kVA, 3·3kV/415V Lindley Thompson transformers respectively. In both cases the 415V switchgear is Metropolitan-Vickers type " Air " airbreak gear. The supplies to the coal handling plant are split, part being taken from the boiler-house and part from a substation on the site. All distribution fuseboards are by Parmiter, Hope and Sugden, Ltd.

Throughout the plant Mather and Platt squirrel-cage induction motors are used for the electrical drives. The larger drives have 3·3kV windings, connected to direct-on English Electric circuit breakers. The remainder are 415V motors with Brookhirst or Allen West direct-on contactor starters or Ellison oil-break starters.

The 45kV, h.t. supply for the Sturtevant precipitators is provided by a mechanical rectifier, a 50kVA step-up transformer, a regulating transformer, and B.T.H. control equipment. Two Chloride batteries are installed, one of 600Ah capacity gives 110V supplies for switch-closing and tripping, governor motors, various valve-operating motors, emergency lighting, &c. The load is floated off the battery by a " Cycloc " charger with a Hewittic mercury-arc rectifier for quick charging. The other of 120Ah capacity, together with another " Cycloc " charger, provides a 50V supply for all alarms and the house telephone switchboard. A Whipp and Bourne switchboard controls both of these supplies.

Most of the lighting in the plant is fluorescent, with Atlas, Benjamin and G.E.C. fittings. Two supplies are provided and, generally speaking, alternate fittings are fed from each supply. Provision is also made for changing from one supply to the other, and, with this degree of duplication, no other standby was considered necessary. On the coal handling plant mixed mercury and tungsten lighting is used at the bunkers, the crusher house, and the tippler house, and tungsten on the conveyor bridges.

Paper-insulated, lead-covered, steel-wire-armoured cables are used for all e.h.t. and the larger medium tension feeders. The remainder of the wiring is part " Pyrotenax " and part polyvinyl chloride steel-wire armoured.

The power station was designed by the company's engineering staff under Mr. R. E. Newell, chief engineer, Wilton Works.

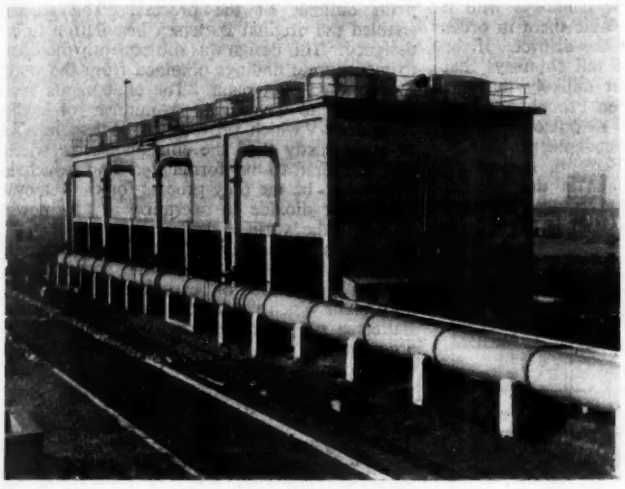

Fig. 8—Induced Draught Cooling Towers

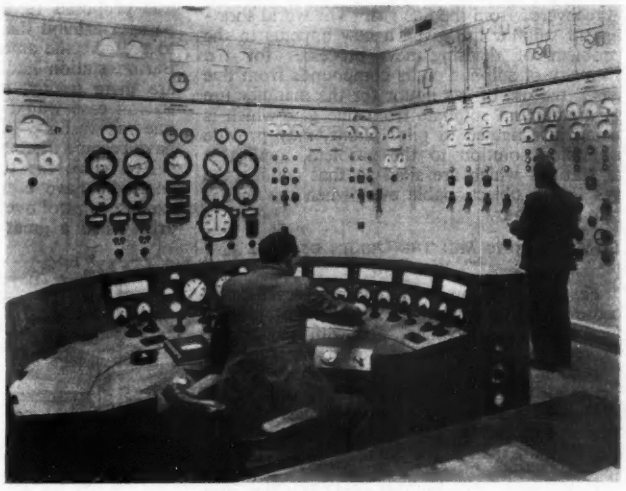

Fig. 9—Steam and Electricity Control Desk and Panels

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

REFERENCE TABLES FOR THERMOCOUPLES

Nos. 1826 and 1827 : 1952. Two sets of reference tables for thermocouples have been published by the British Standards Institution. No. 1826 deals with platinum/rhodium *v.* platinum thermocouples, and No. 1827 with nickel/aluminium *v.* nickel/chromium thermocouples. These reference tables are for use in converting thermocouple voltages into the equivalent measured temperatures and in defining the relation between impressed e.m.f. and scale reading for pyrometers which indicate temperature directly. The tables for platinum/rhodium *v.* platinum thermocouples are based on the tables formulated by the National Physical Laboratory, which have been the basis of reference in the United Kingdom for many years. The tables for nickel/aluminium *v.* nickel/chromium thermocouples are based on the tables formulated by the National Bureau of Standards of America, since no other tables are in common use in the United Kingdom.

The tables specify the e.m.f./temperature relations for the thermocouples in four ways, as follows :—(*a*) millivolts/deg. Cent.; (*b*) deg. Cent./millivolts ; (*c*) millivolts/deg. Fah.; (*d*) deg. Fah./millivolts.

Price, No. 1826, 7s. 6d.; No. 1827, 6s.

The Removal of Oxides of Sulphur from Flue Gases*

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SUMMARY

The paper begins by tracing the historical development of flue gas washing at power stations. The development came about as a result of public pressure which, it is claimed, did not distinguish sufficiently between discharges from short and tall chimneys. Modern knowledge concerning the effects of sulphur dioxide upon men and plants has yielded no evidence for the thesis that ordinary flue gas, discharged hot and at reasonably high speed from well-designed chimneys, is harmful to health or to agriculture; on the other hand, washing the flue gas opposes the good effect of a tall chimney by cooling the gas, so that washing may actually increase the local pollution in certain states of weather. It is calculated that existing gas washing processes (which are described briefly) cost the community more than the damage done by the sulphur dioxide that they remove). These processes are wasteful in that no useful material is recovered from the flue gas. The world shortage of sulphur has given a new impetus to the problem of devising new processes for the recovery of sulphur or its compounds from flue gas; the use of gas liquor for the manufacture of ammonium sulphate from flue gas, which is being investigated in pilot plants, may provide a limited solution to the problem, applicable at stations which are sited so that cooling the gas is not objectionable even when the fuel is rich in sulphur.

Low Chimneys and the Origin of Flue Gas Washing

Fumifugium, John Evelyn's famous seventeenth century diatribe against "the smoake of London,"[1] is principally concerned, not with the smoke from "the culinary fires . . . but from some few particular tunnels and issues, belonging only to brewers, dyers, lime-burners, salt and soap-boilers, and some other private trades. One of whose spiracles alone, does manifestly infect the air, more than all the chimneys of London put together besides."

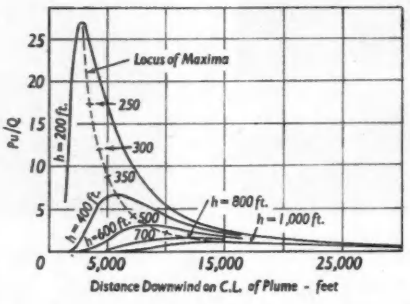
Gases were evidently discharged at a low level in those days, for the Editor of the 1772 edition of *Fumifugium* remarked that "Many of these buildings have no chimneys, and appear to be constructed purposely to beat the smoke downwards."[2] He recommended: "Till more effectual methods can take place, it would be a great service, to oblige all those trades who make use of large fires, to carry their chimneys much higher into the air than they are at present; this expedient would frequently help to convey the smoke away above the buildings, and in a great measure disperse it into distant parts without its falling on the houses below. Workmen should be consulted, and encouraged to make experiments, whether a particular construction of the chimneys would not assist in conveying off the smoke, and in sending it higher into the air before it is dispersed."

If this recommendation had been kept steadily in mind by industrialists and engineers it is probable that flue gas washing would never have been needed at power stations. The development of the principle of natural draught did indeed improve combustion and lessen the emission of smoke and tar. The tall chimney and the relatively high gas temperature which cause the draught helped to dissipate the products of combustion into the upper air.

After the invention of mechanical draught, tall chimneys and high gas temperatures were no longer economic, so that it became the practice at power stations to discharge the gases at a temperature of about 250 deg. to 300 deg. Fah. from chimneys that extended only a little way above the roof. Wind passing over a building forms eddies on the leeward side which carry the air stream down to ground quite near the building, and gas discharged just above roof level is readily caught in the eddies and brought to ground before it has been diluted and dispersed by atmospheric turbulence.

This effect occurred at the Barton power station of the Manchester Corporation. Flue gases from coal containing about 2·2 per cent sulphur were brought down on the land of a neighbouring farmer, who claimed damage. Manchester Corporation denied liability and won the case at Manchester Assizes; but the Court of Appeal reversed the judgment, deciding for the plaintiff with one judge dissenting,[3] a decision which was finally upheld in the House of Lords in November, 1929.[4] This exciting legal battle between a farmer and the corporation of one of our largest cities naturally attracted interest and publicity, which were quickly transferred to the projected new power station at Battersea, the building of which had just been begun. Few people realised that the lessons to be drawn from the Barton case applied only to stations with low chimneys; the effects at Barton were in fact worsened by the low velocity, about 14ft per second, at which the gases were discharged. Tall chimneys were regarded as æsthetically undesirable in those days; for example, in the London Joint Electricity Authority's scheme for a station at Chiswick, which just preceded the Battersea scheme, it was proposed to install low chimneys with a parapet around the roof to hide them in order to preserve the amenities of the district. If the Barton station had had the tall chimneys that are there to-day, it is most unlikely that the Barton case would have been brought, or that flue gas washing, which was its outcome, would have become more than an academic problem.

Ever since the time of Ferranti, responsible engineers have been conscious of the need to exercise control over the disadvantages that may arise when a great deal of coal is burnt in a small area, as is done at power stations. In consenting to the construction of the first third of Battersea power station, the Electricity Commission imposed in October, 1927 (i.e. before the Barton case) the condition that the London Power Company should "take the best-known precautions for the due consumption of smoke and for preventing as far as reasonably practicable the evolution of oxides of sulphur." This condition might have been met by burning washed coals containing less than 1 per cent of sulphur, but the public reaction to the Barton case made it abundantly clear that this precaution would not suffice to ensure official consent to the completion of Battersea power station beyond the first third for which consent had already been granted. The London Power Company thus had a choice of two alternatives: they could either abandon the Battersea workings and try to find another site about 20 miles down river, or they could continue at Battersea and find a successful method of removing sulphur dioxide from the gases. The first choice involved an additional charge for transporting electricity equivalent to about 0·025d. per kilowatt-hour, and carried no guarantee that the development of gas washing would not be imposed as a condition of the official consent to this new station. The second choice involved the development on a huge engineering scale of a process about which nothing was known except that more than twenty years earlier Messrs. Rowntree had removed sulphur dioxide in a washer intended to deal with dust and smoke from a Lancashire boiler.[5] A few experiments confirmed that a washing process was feasible, and Dr. Pearce (later Sir Leonard Pearce), with whom the effective decision rested as engineer-in-chief of the company, chose to proceed with the Battersea plan. For its faith and resolution this must rank high among the difficult decisions in the history of engineering.



P = ground-level concentration, in p.p.m. sulphur dioxide by volume.
u = wind speed, in m.p.h.
Q = sulphur dioxide discharged, tons sulphur per hour.

Fig. 1—Typical Ground-Level Concentrations of SO_2 on the Centre Line of a Gas Stream Discharged at height h

Pilot Plant Researches for Battersea

There is no need to retell in any detail the story of the London Power Company's pioneering researches; they have already been amply described.[6, 7, 8, 9, 10] The work was taken immediately to the pilot plant stage because the building of Battersea power station had begun, and there was no time to try to fill, by a preliminary study on classical lines, the extensive gaps that existed at that time in the relevant data of physical chemistry, and in the chemical engineering theory of mass transfer.

Three pilot plants were built at Grove Road power station. Work on the first yielded the main outlines of the process. The second enabled the original Battersea installation to be designed. This design was subsequently modified to incorporate findings obtained from the work on the third pilot plant. The pilot plants were also used to investigate a number of cyclic processes,[9, 11] which proved to be less reliable or more costly than the effluent scheme which was the first to be formulated and which is believed to be the only process for the removal of sulphur dioxide in operation at any power station in the world to-day.

It may be interesting at this point to anticipate events in order to illustrate the scope of the semi-scale method of experimentation. The pilot plant which yielded the design data for the Battersea plant treated gases corresponding to a coal rate of 4 tons per hour at full load. The corresponding coal rate for the Battersea plant was 133 tons per hour. It was designed to remove "about 90 per cent of the oxides of sulphur from gas derived from coal containing 0·8 to 1·0 per cent sulphur."[9] The original Battersea "A" plant worked for about seven years; during the last three, when it was fully loaded with gas from the boiler installation which was by that time complete, it treated 600,000 million cubic feet of gas derived from 1·4 million tons of coal containing an average of 0·88 per cent sulphur, of which only 9 per cent escaped into the atmosphere, in excellent agreement with the design figures. But semi-scale experiments do not give adequate information about the design of plant for minimum cost of maintenance unless they are continued for a long time; the maintenance problem at Battersea is still very costly despite the many improvements that have been made.

[Here the author outlined the theory of SO_2 removal and discussed the original Battersea process,[9] the modified Battersea process, the Howden-I.C.I. process and other methods of dealing with SO_2.]

Discharge of Flue Gases from Chimneys

Power stations burn only about one-fifth of the total coal consumed in the United Kingdom. Since their economic purpose is to burn fuel with greater efficiency than is possible in factories, offices and homes, the effect is to lessen the overall discharge of sulphur dioxide into the air, and consequently to lessen the general level of pollution. The natural consequence of this centralisation, the risk of increasing the level of pollution immediately around the stations, may be countered by discharging the gases from high chimneys.

The high chimneys of the power station, even though their height may be limited in practice by the current taste in architecture or by danger to low-lying aircraft, give the gas a much better opportunity of dispersing before it comes into contact with other objects than if it were discharged from houses, offices, or even from other and smaller factories.

A study of the path taken by the plume of gas after leaving the chimney is an inseparable part of the gas washing problem. There is no

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better illustration of this than the behaviour of the gas discharged from Battersea power station. The few complaints that have been made about downwash of gas from this station were all received while the gas washers were operating; the author is not aware of any having been received while the washers were out of action during and after the war. There has always been good reason to believe that the washed gas from Battersea comes to ground more readily than unwashed gas, and the fact was proved when the gas washers were being restored to service, for a direct comparison could then be made between the behaviour of washed gas from one chimney and that of unwashed gas from its neighbour. The downward trend of the washed gas could be clearly traced against the horizontal or upward trend of the unwashed gas.[12] The effect is most obvious at the lower wind speeds and is not seen when the wind is blowing strongly; this agrees with observations made upon cool oil fog discharged at a height of 200ft into an unstable atmosphere composed of thermally maintained eddies.[13] The downward trend is enhanced if gas passes over a relatively cool region, where it may be caught in downward currents of air. This downward trend of the gas is closely related to the cooling which is inseparable from gas washing. We have to inquire whether flue gas washing can offer any real benefit to the community if it causes the gas to reach ground level much nearer to the chimney and therefore much less diluted by atmospheric turbulence than would be the case if it were discharged unwashed.

A great deal of theoretical and experimental work has now been done upon the problem of what happens to gases after discharge from a tall chimney. The theory, which involves the theory of atmospheric turbulence, is elusive. Wind tunnel experiments have given much helpful guidance, especially in the design of chimneys for specific power stations; but when applied to the general problem they have the defects that the atmospheric temperature gradients and the turbulence of the wind approaching the chimney cannot be properly reproduced, so that they cannot give to the theoretical development the reliable experimental background which it needs and which can only come, as it now seems, from long-continued programmes of field observations.

Bosanquet and Pearson[14] developed theoretical equations for the spread of gases from tall chimneys. The mathematical treatment was extended by Sutton,[15] whose equation for the concentration at ground level is:

$$P=\frac{2Q}{\pi C_y C_z u x^{(2-n)}}\times exp.\left[-\frac{1}{x^{(2-n)}}\left(\frac{y^2}{C_y^2}+\frac{h^2}{C_z^2}\right)\right] \quad . (1)$$

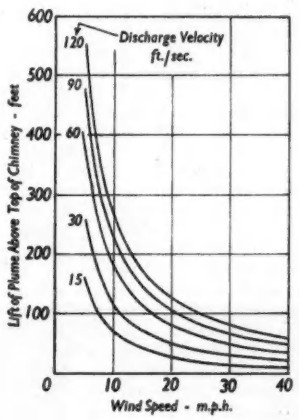
where P is the concentration (in grammes per cubic centimetre) of polluting material at ground level x cm down wind and y cm across wind (measured from the centre line of the gas stream), when Q grammes of such material per second are emitted from a chimney h cm high into a wind having a mean velocity u cm per second. C_y and C_z are virtual diffusion coefficients in the cross wind and vertical directions whose values depend upon the eddy velocities and the turbulence. The number n may have values increasing from 0 to 1 as the atmospheric turbulence increases; according to Sutton, n is about 0·25 under average conditions.

A large number of observations have been made in America on smelter chimneys ranging in height from 146ft to 605ft. Thomas, Hill and Abersold[16] have compared the results with the Bosanquet-Pearson equation, and with Sutton's equation. The former equation expresses the results satisfactorily, but a slightly better fit seems to be given on the whole by Sutton's equation when n is made equal to zero, and $C_y=C_z=0{\cdot}07$. As we are concerned with the maximum concentrations in the line of the gas stream, $y=0$. Fig. 1 expresses equation (1) in practical form after these numerical values have been inserted. The maximum ground concentrations, which occur 14·3 chimney heights down wind when $n=0$ and $C_z=0{\cdot}07$, are represented in Fig. 1 by the dotted line which passes through the highest points of the curves.

Fig. 1 should not be regarded as anything more than an empirical statement in which theory has been used for smoothing and extrapolation. The reality is more complicated. For example, the vertical diffusion coefficient C_z may be much smaller than the horizontal coefficient C_y when the atmosphere is stable, so that the plume of gas fans out sideways and spreads little in the vertical plane, giving lower concentrations at the ground; conversely, in an unstable atmosphere when the ground surface is warmer than the air and the wind speed is fairly low, vertical currents of thermal origin waft the plume upwards and downwards so that it touches ground momentarily much nearer the chimney. According to Church,[13] who made over 40,000 photo-electric observations on cool oil fog discharged from a 200ft stack, the state of the atmosphere has an overriding control over the ground concentrations; contrary to the theories of Bosanquet and Sutton, Church could find no definite relationship between wind speed and dilution, apart from the association of wind speed with atmospheric stability.

The value of high chimneys is well illustrated by Fig. 1. They have an additional virtue in that the effective chimney height may often be enough to bring the gas above the stagnant lower layer of air that exists during inversions of atmospheric temperature. This layer is seldom deeper than 400ft, and there is often a good wind above it.[17]

The effective height of a chimney may be diminished by the contour of the ground and by surrounding buildings. A technical committee appointed by the Electricity Commission reported in 1932[18] that the height of chimneys should not be less than 2·5 times the height of the highest point of the power station buildings; but it has since been found in the course of wind tunnel experiments that obstructions up-wind can set up eddies which promote downwash from the chimney even when this condition is met, so that attention has been given to the shaping of power station buildings from an aerodynamic point of view.[19]



The volume of discharge corresponds to a plant loading of 120MW.

Fig. 2—Influence of Velocity of Discharge Upon the Lift of the Gas Stream above Chimney Top Level

The effective height of a chimney may be increased substantially by lowering the density of the gas (raising its temperature), and by increasing the velocity with which it is discharged. Bosanquet, Carey and Halton[20] have examined theoretically the influence of discharge velocity and temperature upon the path of the plume; they obtained reasonably good experimental confirmation of results predicted by the theory.

If the density of the gas is the same as that of the atmosphere the velocity of discharge will carry the plume upwards to a maximum height above the chimney top, at which level the axis of the plume becomes horizontal. The amount of lift calculated by the formula of Bosanquet, Carey and Halton is plotted in Fig. 2, against wind speed for a number of discharge velocities ranging from 15ft to 120ft per second. The momentum of the gas is involved as well as its velocity; for example, an increase of momentum may enable the gas to overcome eddies which would otherwise carry it downwards.[21] Fig. 2 has been calculated for a gas discharging capacity corresponding to a plant load of 120MW. According to Bosanquet, Carey and Halton, the lift of the gas is proportional to the square root of the volume discharge rate, a relationship which enables the data of Fig. 2 to be applied to other volume discharge rates.

The principal feature of Fig. 2 is the large amount of lift which can be obtained at low wind speeds by increasing the velocity of discharge. This is especially valuable because it is at low wind speeds, when the atmosphere is unstable, that the gas is most prone to touch ground near the chimney.

The chimney at Bankside power station was limited in height so that it should not compete architecturally with St. Paul's Cathedral. The effective height has been raised by increasing the velocity of discharge, and the chimney consists of separate ducts which can be shut off one by one in order to maintain the velocity at lower outputs and in order to make the most of the momentum effect. The chimney height at New York's Astoria station has been limited because the station is near La Guardia airfield; special discharge nozzles have been devised for these chimneys to increase the discharge velocity; the higher velocity can be maintained at half load by controlling the orifice of discharge. Chimney nozzles of simpler kind have been fitted at several power stations in the U.S.A.

Bosanquet, Carey and Halton also derived a formula expressing the influence of temperature upon the lift of the plume above the chimney top.[20] The scope of their equation is restricted to certain states of the atmosphere, so that it is more convenient for general purposes to turn to the results of field observations upon chimneys. According to P. J. O'Gara, quoted by Hill, Thomas and Abersold,[22] field observations with a stack heater have shown that each 1 deg. Fah. rise is equivalent on the average to raising the chimney height by 2·55ft. Unwashed flue gas is usually discharged from power stations at a temperature which is about 200 deg. Fah. above the temperature at which the density of the gas is equal to that of the surrounding atmosphere. When gas is washed by a cyclic process it is cooled almost to its wet bulb temperature, usually to about 130 deg. Fah. at a coal-fired station. In the Battersea gas washing process the gas is cooled by another 20 deg. to 40 deg. Fah., the discharge temperature depending upon the temperature of the river water with which the gas is washed. If O'Gara's figure can be accepted, washing the gases is equivalent to reducing the effective chimney height by 350ft to 400ft. According to Fig. 1, the maximum value of Pu/Q at ground level is thereby multiplied four and a half to six times when the effective chimney height at full gas temperature is about 700ft. This means that under ordinary atmospheric conditions a gas washing process must be at least 80 per cent efficient before there can be any improvement in the maximum sulphur pollution around the chimney; at low wind speeds, observation shows that the ratio is even more unfavourable than this. The maximum ground concentrations of other constituents of the flue gases, which are relatively harmless, are of course increased in full ratio, since they are not removed by washing the gas. There is here a theoretical explanation for the observation which was made earlier in the paper that the only complaints about the emission of gas from Battersea power station were received when the gases were being washed.

The figures which have been presented in this section of the paper illustrate the way in which a low maximum ground concentration of all constituents of the flue gases may be secured by discharging the gas hot and at high speed from chimneys that are as tall as amenity and aircraft interests will allow.

Costs and Pollution

A careful survey of the cost of atmospheric pollution was made by the Egerton Committee of the D.S.I.R. Building Research Board.[23] At 1938 prices, the cost to the community of pollution arising at power stations was estimated to be about 2s. 2d. per ton of coal burnt, of which 2s. 1d. was for sulphur dioxide. By comparison, pollution from the domestic coal fire was estimated to be 8s. 1d. per ton of coal, of which 1s. 11d. was charged to sulphur dioxide.

These costs covered damage to buildings and textiles, but not to crops or to health. It may be noticed in passing that smoke is responsible for most of the difference between the costs for total pollution arising from the power station on the one hand and the domestic coal fire on the other.

The figures may be brought approximately to modern values by multiplying by a factor of 3·2, giving 6s. 8d. per ton of coal burnt as the cost of pollution by sulphur dioxide discharged from power stations of the kind that were in use when the Egerton report was drawn up. As power stations that have been built more recently have taller chimneys which disperse the gases much more effectively, 6s. 8d. is too high a figure for present-day and future conditions.

To install and operate the Battersea process at a new station at the present day would cost about 7s. per ton of coal burnt. This process can only be employed near a large river or the sea, owing to the large quantity of water that is used in it. The Howden-I.C.I. process would cost about 10s. per ton of coal burnt. Both of these costs omit an important item which cannot easily be estimated in advance: the effect of the process upon the efficiency and availability of the generating plant. Gas washing plant is particularly troublesome to maintain. If generating plant to which it is connected has to be shut down for repairs to the gas washer, the electrical load must be supplied from other stations, which are nearly always among the least efficient. Thousands of tons of coal can be wasted very quickly in this way. Flue gas washing does not, of course, reduce the cost of pollution to zero; owing to the cooling of the gas, which prevents it from dispersing as effectively as unwashed gas, the reduction in cost of pollution must be less than proportional to the amount of sulphur dioxide removed in the process. If all these factors are weighed, it will be seen that flue gas washing, by the cheaper Battersea process, costs the community more than the damage done to buildings and materials by the unwashed gas, even when the unwashed gas is emitted from short chimneys. The difference when the hot gas is discharged from tall chimneys must be substantial.

The effect of sulphur dioxide in the atmosphere upon plant life has been studied more thoroughly than any other aspect of pollution. Damage may be done to specially sensitive plants by sufficiently long exposures to concentrations exceeding 0·25 p.p.m. SO_2; it is always accompanied by visible injury to the leaves or other parts of the plant. Lower concentrations do not damage plants; in fact, concentrations within the range 0·1 to 0·2 p.p.m. may be beneficial if the soil in which the plants are growing is deficient in sulphur.[24] This statement summarises an immense amount of experimentation, much of which formed part of a comprehensive study of smelter operation in Canada and the U.S.A., where pollution by smelters was an international problem.

Compared with the agricultural aspect, the health aspect of pollution by sulphur dioxide has received little serious attention, although it rightly attracts the most interest in this country. A study[25] has been made at Abadan of the health of workers who had been exposed to sulphur dioxide daily for periods varying from one to nineteen years. The concentrations ranged from zero to 25 p.p.m. and sometimes reached 100 p.p.m., values that are much higher than those found around power stations. No adverse effects upon the health of the workers could be detected. In an extensive review of air pollution in the U.S.A.[26] it was said that acute exposure to irritant gases such as sulphur dioxide lowers the resistance to acute respiratory infections, according to present evidence, only when the exposure is severe enough to damage the mucosa of the respiratory tract; there is very little, if any, evidence to indicate that prolonged exposure to smaller concentrations lowers the resistance to acute respiratory infection. Neither acute nor prolonged exposure lowers the resistance to tuberculosis.

Experienced observers cannot detect sulphur dioxide by smell or by taste when the concentration is less than about 2 p.p.m., so that the gas is not obnoxious to the senses below this level of concentration.[27] The findings at Abadan and in the U.S.A. make it reasonable to suppose, at least provisionally, that these concentrations are also non-injurious to health when the exposures are no more continuous than those to which the workers at Abadan were subjected.

Conclusion

When all the factors are brought into consideration there are seen to be good reasons for believing that to discharge the gas hot (i.e. unwashed) at reasonably high speed from tall chimneys is, according to present knowledge, the best answer to the problem of pollution by sulphur dioxide emitted from power stations when normal fuels are being burnt. It should be possible, even at the least favourable wind speed[17] of about 10 m.p.h. to keep down the local ground concentrations of sulphur dioxide in this way to levels that are neither obnoxious nor injurious to human beings, nor even harmful to plants, some of which are more sensitive to sulphur dioxide than human beings. Washing the gas may cool it enough to undo much of the good done by removing the sulphur.

Although this solution of the problem does not greatly affect the general level of pollution in the atmosphere by sulphur dioxide, which is believed to be responsible for some of the corrosion of metals and stonework, the overall cost to this island community, calculated from the estimates of the Egerton Committee, is less than that of applying the Battersea gas washing process, and a good deal less than that of applying the cyclic lime process.

The products of these two processes are wasted, in the Battersea process by design, in the cyclic lime process because cheaper calcium sulphate is easily obtainable elsewhere. Both processes therefore become more costly as the proportion of sulphur in the coal increases, so that they are not contrived for purifying gases derived from fuels of very high sulphur content. These gases can present new problems to the designer when, for reasons that are outside his control, he is unable to provide the extra chimney height that is required in order to disperse them satisfactorily.

Processes in which a saleable product is recovered can be expected to become cheaper, or at least no more expensive, as the sulphur content of the gas increases. Unfortunately, owing to the fact that washing the gas causes it to reach ground level nearer the chimney, it is only processes of the highest efficiency that can be tolerated at power stations, especially when the fuel contains a high proportion of sulphur. The problem will have a new aspect if more of such fuels are sent to power stations. The Fulham-Simon-Carves process, which is being investigated in small pilot plants, may provide a limited answer to it in the rather artificial and perhaps transitory economic circumstances of to-day, in which scarce elementary sulphur is degraded to the common sulphate radical for use in the manufacture of ammonium sulphate. This process uses gas liquor and some sulphuric acid as raw materials, and produces ammonium sulphate and sulphur. Sites at which even highly efficient processes can be used may prove to be few in number when the fuel is unusually rich in sulphur.

Although many other recovery processes have been suggested, and some of them have reached the stage of pilot plant investigations, none has shown signs of being successful commercially when applied to flue gases. The world shortage of sulphur has given a new impetus to the study of this problem.

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High-Pressure and High-Temperature Jointing Materials

We have received from James Walker and Co., Ltd., of Woking, Surrey, particulars of two recent products, "Metaflex" gaskets and "Twistele" jointing, which it has introduced to meet modern requirements for jointing materials capable of withstanding the greatly increased pressures and temperatures now used.

The "Metaflex" gaskets are made from a spirally wound strip of vee-shaped stainless steel with a cushion of filler material—usually asbestos paper—interposed between each turn in the spiral. When the gaskets are placed in a joint the edges of the steel strip are gripped between the two locking faces and, as a gasket is compressed with the tightening of the joint, the vee-shape of the strip is retained. The natural spring return effect of the strip maintains an effective seal with good recovery properties, which enables the joint to withstand the effects of vibration or extreme temperature changes and the resultant expansion or contraction of metal parts and variations in the applied loading.

The makers point out that whilst these gaskets were designed originally for high-pressure, high-temperature and superheated steam applications, their use is not confined to steam service. They can be adapted for a wide range of application as the number of metal plies in relation to filler plies can be increased or decreased and the filler material itself varied to suit practically any service conditions. Specially manufactured gaskets are being used in connection with such services as air, water, oil, many gases and chemicals, and they are also satisfactory for use in low-pressure steam conditions where normally flanges are difficult to keep tight owing to condensed steam.

When they are used for high-pressure steam and other types of open pipe flanges, it is usual to equip the gaskets with an outer steel guide or retaining ring. This ring acts as a simple and accurate means for centralising the gasket inside the bolt circle. It also acts as a support and a compression gauge to limit lateral expansion and prevent undue compression being applied to the gasket, which would tend to impair its natural recovery properties and reduce its life. The guide rings have a vee-shaped groove machined in the inner surface to correspond with the outer profile of the gasket. This arrangement facilitates the supply and installation of the gasket and guide ring as a single unit, but the design is such that the gasket may be removed easily from the guide ring should necessity arise.

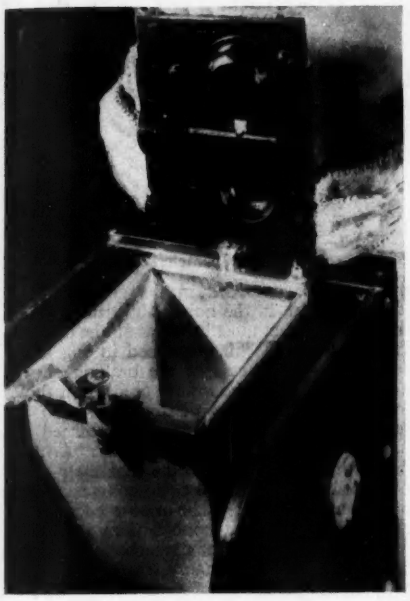
The "Twistele" flange jointing material for high-pressure and high-temperature applications is made from long-fibre asbestos yarn with steel wire running through the centre of each strand. During manufacture a reinforcement of steel wire is closely interwoven in a twill weave. The material is impregnated with an oil-resisting compound incorporating graphite to prevent gaskets clinging to the flanges. This jointing material is stated to have great tensile strength and heat-resisting properties, combined with a degree of compressibility that will overcome slight flange irregularity.

Christmas Lectures for Boys.—The Institution of Civil Engineers' Christmas lectures for boys this year deal with the jet aircraft and civil aviation with particular reference to the "Comet" aircraft. The first of them is to be delivered at 3 o'clock to-day and the other two on December 22nd and 29th.

Shell Moulds and Cores

WE have received from Bakelite, Ltd., of 12, Grosvenor Gardens, London, S.W.1, some notes on the synthetic resins it has developed for use in shell moulding. This technique of producing foundry moulds and cores in the form of thin shells based upon a mixture of sand and synthetic resin binders lends itself particularly to the mass production of castings, and three separate grades of resins have been developed by the company to meet varying requirements.

Metal boxes or patterns are used in the process which depends upon the heat-hardening properties of certain powdered phenolic resins. When small proportions of these resins are mixed with dry sand and dropped on to a heated metal pattern, the thermosetting nature of the resins causes a thin shell to be formed, reproducing with great accuracy the contours of the pattern. By the application of additional heat, the curing



Pattern Being Set on Bucket

of the resin in the shell is then rapidly completed and a hard, porous half-mould or shell is obtained, which, when set up with the other half, is ready for pouring.

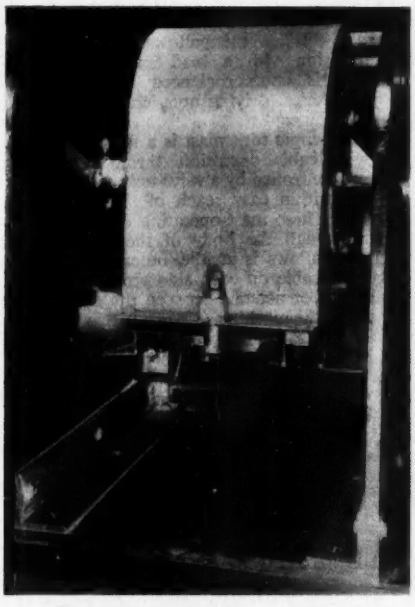
Amongst the advantages offered by the process is economy in the use of sand, only small quantities being required in relation to the weight of metal poured. The proportion of resin needed for bonding, moreover, has been found to amount generally to between 5 and 10 per cent of the sand used, with the lower figure proving adequate in most cases. The shells themselves are sufficiently rigid for all reasonable handling, and can be stored indefinitely in a comparatively small space. In this way mould and core-making can be separated from actual casting and a bank of finished shells built to buffer production schedules. Because of the method employed, complicated designs can be produced as easily as simple ones, the finish of the shell depending entirely upon the accuracy of the original pattern. Very fine details can, in fact, be obtained and, in general, work to considerably closer tolerances is made possible with consequent saving in finishing costs, particularly in machining.

In the mould-making process the first step is the preparation of the resin/sand mixture, for which the sand used should be a dry, highly refractory, pure silica sand free from clay and other contaminants. We are informed that for most purposes a fairly fine sand of which the bulk passes 60 mesh but is retained by 200 mesh, is suitable, and the mixture used consists of 5 parts by weight of resin to 100 parts by weight of sand. Very thorough mixing is essential and the distribution of the resin through the sand can be materially assisted by mixing 0·5 per cent of wetting agent into the sand before adding the resin. Generally, the 5 per cent of resin mentioned above gives satisfactory results, but in certain cases a small increase in this amount, such as when using very fine sands, can give better results.

The mould-making sequence can be seen in the photographs we reproduce on this page of equipment used in the laboratories of Bakelite, Ltd. The mixture is loaded into a bucket which is mounted on trunnions on a stand, so that it may be inverted quickly. A metal pattern, previously heated to 365 deg. to 500 deg. Fah. and lubricated with a suitable parting agent, is then fixed securely over the open top of the bucket and the whole apparatus inverted. By this means the resin/sand mixture is thrown or dumped on to the hot pattern and it is allowed to remain there until a shell of sufficient thickness is formed. From ten to forty seconds is usually sufficient for this part of the operation, though, obviously, this "dwell time" depends on the thickness of the mould required for any particular casting. The bucket is then swung down to its original position and the remaining resin/sand mixture is ready for the operation to be repeated.

The pattern is removed from the bucket and placed in an oven for the final hardening of the shell mould, which is usually carried out at a temperature of 550 deg. to 700 deg. Fah., and takes from one to five minutes according to the shell thickness and the resin used. After this treatment the shell mould is in the form of a hard infusible solid which is removed from the pattern while still hot.

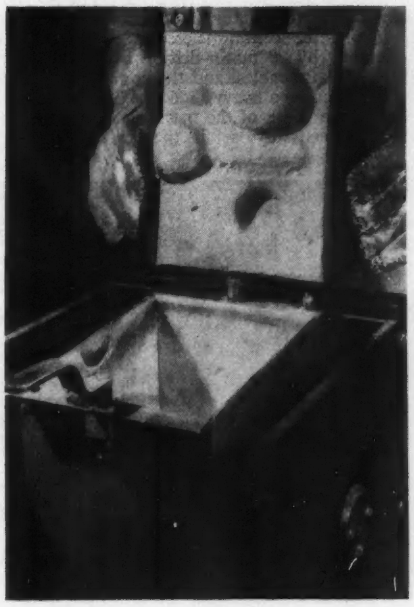
To complete the mould, two half-moulds are held together by any suitable means, such as clips, bolts or soft iron nails. To set up the mould for pouring it is generally adequate to embed it in sufficient depth of sand to hold it firmly in position. The metal is poured in the normal



Bucket of Sand/Resin Mixture Reversed

way and the mould, being porous, allows free escape of gases. Back pressure is reduced to a minimum, resulting in sound castings and the elimination of surface blemishes.

The shell moulds remain sufficiently rigid for accurate casting during the pouring of all metals, but their breakdown is rapid enough, it is stated, to make knock-out virtually unnecessary.



Mould Being Removed on Pattern

The material used for making the pattern plate should have good mechanical strength, be a fair conductor of heat and sufficiently heat resistant to withstand 400 deg. to 500 deg. Fah. for indefinite periods of time and up to 700 deg. to 800 deg. Fah. for short periods. It should also be sufficiently hard to resist scratching and deformation during reasonable handling and be fairly easy to machine. Pattern plates have been made of cast iron, steels, aluminium, brass and gunmetal.

Shell cores can be produced by similar methods on the inside of hot split, metal-core boxes, and, since the resin/sand mixture will fuse evenly to a section which has already been cured, the build-up of intricate cores in one piece becomes possible.

Two Industrial Fork-Lift Trucks

Two new designs of fork-lift trucks are now being made by Cleco Electric Industries, Ltd., Foundry Square, Leicester, and a demonstration of these machines was recently held at the firm's works.

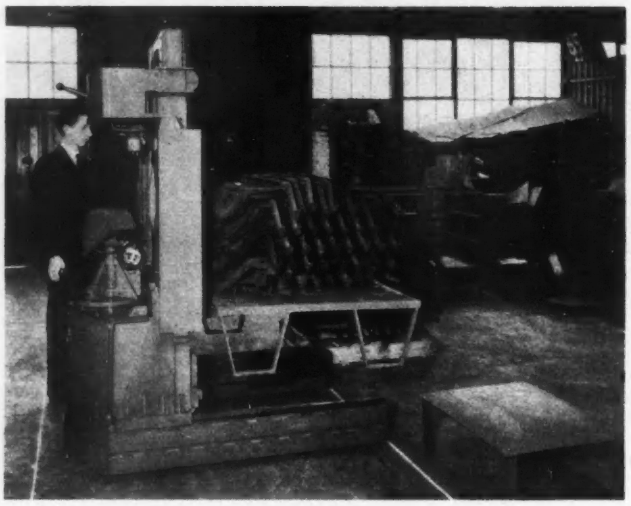
The largest of the trucks which is designed, for use in factories with level concrete floors in a good condition, has now been put into production after extensive tests with a prototype machine. It is a swivelling head, high-lift machine capable of handling loads up to 2000 lb from floor level up to a height of 8ft 4in. The design of this truck is such that, although it has an overall width of just over 4ft, it can be used for stacking and moving loads on gangways only 4ft 9in wide without need for undue manœuvring of the machine itself.

The machine weighs about 43 cwt and is rigidly constructed of heavy welded steel sections and plate. It is built on a substantial base plate, carried an inch or two above floor level on two 6in diameter wheels at the front corners, and a large single driving and steering wheel in the centre near the rear. Steadying wheels are fitted at each of the rear corners to give additional stability. The two-speed driving unit is of the firm's standard design, consisting of a large wheel driven through chains by a ½ h.p. electric motor and arranged for tiller steering. Through this steering tiller automatic brake application is made by release of the tiller, and a simple switch controls direction of travel. The operator of the truck can either walk with the machine or stand on a small platform when travelling any distance.

The base plate is extended forwards to form a platform at the front of the machine, and a rigid fabricated cabinet structure built over the rear part encloses the operating equipment, batteries,

propelling and steering unit, &c., and provides the support for the fork mast assembly.

The three-section telescopic fork mast is operated by a motor-driven hydraulic pump through wire cables, and the complete assembly is mounted on a heavy slide which can be moved across the width of the truck on rollers running in machined ways set in the cabinet front. A



Travelling Gallows Fork-Lift Truck

compound endless chain which is used to traverse the mast assembly across the machine is driven by a small electric motor and has a heavy counterweight attached to one end. With this arrangement the counterweight is automatically traversed to the opposite side of the machine to maintain the correct balance as the fork assembly with its load is moved.

The forks themselves are mounted on a massive swivelling head through which they can be swung through 180 deg. to set at right angles on either side of the machine. This swivelling movement is actuated by two hydraulic jacks built into the head and operating on a closed circuit. A short "crowding" movement can be imparted to the forks to set them completely home when picking up pallets from positions immediately adjacent to the side of the truck. The picking up and placing of loads in

Swivelling Head Fork Lift Truck

confined spaces is effected with the forks at right angles, as shown in the photograph we reproduce, and movement of a load into or out of a stack is then carried out by traversing the mast assembly across the width of the machine. In open spaces the truck can be used for loading and unloading in the normal way with the forks projecting straight out in front of the machine. Whilst the truck is moving or being manœuvred the forks and their load are generally set at right angles and withdrawn within the compass of the machine.

The other new fork-lift truck is designed to handle loads of 2000 lb to levels of up to 8ft, and it has an overall turning circle radius of 3ft, which enables it to be operated and revolved, complete with load, with reasonable ease within aisles of only 6ft. It weighs only 27 cwt and is of the maker's latest travelling-gallows, counterbalanced, load-withdrawal design suitable for the rougher factory floors.

The general design of the machine can clearly be seen in the first illustrations on this page. It is a battery-operated truck of rigid fabricated steel construction propelled by the firm's standard tiller-steering drive unit. The main body of the machine incorporating the drive, power unit, battery compartment, &c., has a heavy built-up channel section beam projecting forwards from each side of its base. These beams carry the front support wheels and the "gallows" structure embodying the fork mast travel along these beams.

The front support wheels are mounted in carriages which, through a chain linkage, are moved along in the channels of the beams as the gallows moves in and out. With this arrangement the gallows is given the maximum support in all positions along the beams whilst the effective wheel base is kept to a minimum for manœuvring purposes. When the gallows is at its outermost position with a load suspended on its forks, it is counterbalanced by the weight of the batteries, driving unit, &c., on the body of the machine.

The telescopic fork mast is a fabricated structure with cable operation through hydraulic cylinders controlled by a valve unit with a control lever set within easy reach of the operator at the rear. These mast-operating cables are connected through the body of the machine and when the gallows is at the outermost position the run of cable on each side prevents unintentional entry of persons between the gallows and the body of the machine.

When it is required to handle a load the machine is positioned squarely in front of the pallet with the gallows fully retracted. Then, with the forks at the required level, the gallows is run forwards, and after the forks have been raised to suspend the load, the gallows is fully retracted. The machine is then free to turn on its shortest possible wheel base for the manœuvring of the machine along narrow aisles.

An Improved Rheostatic Brake for Trolleybuses

AN improved system of rheostatic braking for trolleybuses has been developed by the General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. It is designed to overcome, as far as possible, the disadvantages of some existing forms of rheostatic braking which suffer from variations in the braking effort because of changes in the temperature of the motor field winding.

In most trolleybuses equipped with compound-wound motors both fields are used for motoring, the main excitation for the rheostatic brake being provided by the separately-excited field. In some instances this field is used alone; in others it is associated with a few turns of the series field, as inverse compounding; and in others it is associated with the braking resistors (also used as starting resistors) to give a form of inverse compounding characteristic. Our first illustration shows the elements of these three braking schemes and indicates, broadly, their performance. It will be seen that, in each instance, changes in the temperature of the motor field windings cause substantial variations in the braking performance. Since the maximum value of the braking torque is limited by the transmission system, and the permissible value

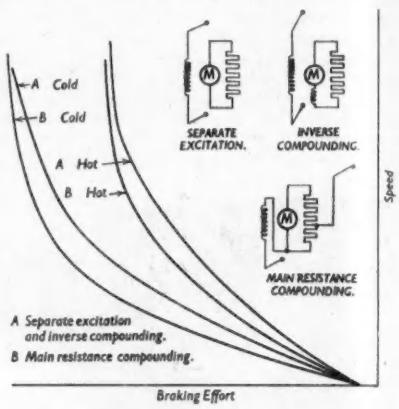


Fig. 1—Typical Rheostatic Brake Circuits and Their Characteristics

must not be exceeded in the cold condition, it follows that, in the normal hot running state, the braking effect must be less than the optimum.

Schemes of the kind outlined in Fig. 1 also suffer from the fact that the braking effort is not maintained at the lower speeds, and though this is no appreciable disadvantage so far as saving of brake maintenance is concerned, it is not ideal from the driver's viewpoint. A further disadvantage is that when the separately-excited field used for excitation is opposed by some turns of the series winding, the motor consequently carries slightly more copper than is required for the production of the magnetic flux.

The improved braking system described here is based on the use of a series winding for motoring. A simplified diagram of the system

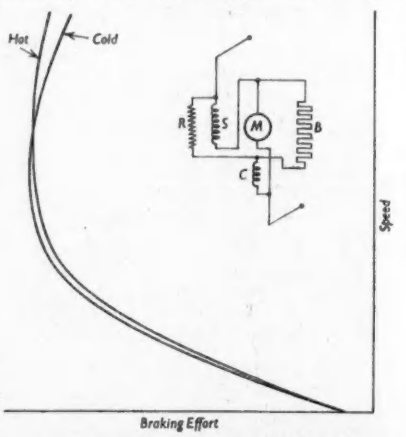


Fig. 2—Simplified Circuit and Characteristics of Improved Rheostatic Brake

is shown in Fig. 2, together with typical performance curves for comparison with those of Fig. 1.

The power circuits are so arranged that only a portion of the series field winding remains in circuit during braking and the current flow relative to the armature is reversed. A braking circuit will therefore be formed, through the armature, the braking resistor *B* and the series field winding *C*. The speed-brake characteristic with this arrangement alone would not be

suitable, but it is so designed that at maximum build-up it will not produce sufficient braking torque to damage the transmission, although it may exceed a safe continuous running torque. This precaution is necessary to avoid damage to the transmission in the unlikely event of the regulating shunt field winding failing. The regulating shunt field winding *S* is energised in series with the motor armature *M* across the line. Thus, when the voltage of the armature *M* is high, at high-speed braking, the armature voltage will exceed line voltage and create inverse excitation. At low speeds the excitation will be cumulative due to the line voltage exceeding the armature voltage.

This arrangement results in a more constant tractive effort curve than those of the older systems, which is an advantage to the driver. The greatest advantage is that with this new system there is very little difference in torque between the hot and cold state. Consequently normal braking torques may be arranged equal to the safe running torque of the transmission and are not limited by considerations of the safety of the transmission in the cold state. By associating the separately excited winding with the motor braking voltage as described in the previous paragraph, it was possible to keep this winding small and to use only a few series turns for braking, with a worthwhile economy in the use of copper.

Should the trolley leave the line the small resistor *R* will maintain sufficient energisation of the separately-excited field winding at high speeds to maintain the high-speed part of the performance characteristic. Some falling off of effort will, however, result at lower speeds.

We are informed that an equipment embodying this form of braking has been in regular passenger service with Reading Transport for over two years.

A Three-Cubic-Yard Dumper

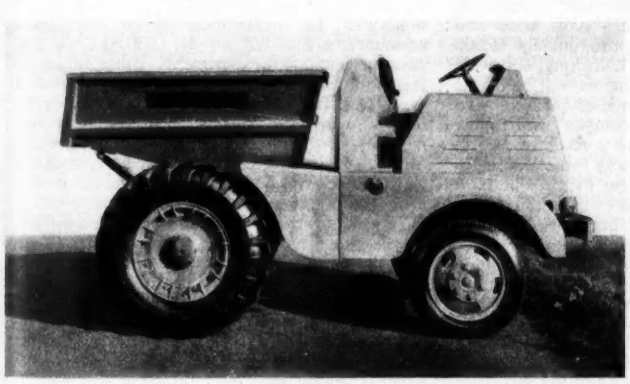
THE photograph we reproduce below shows a new 3 cubic yard capacity dumper, now being made by the Chaseside Engineering Company, Ltd., of Station Works, Hertford. This machine has a forward drive for road operation, but it is also available with the conventional dumper driving position with the operator facing the hopper.

The dumper is driven by a Perkins "P.6" six-cylinder diesel engine developing 60 h.p. at 1800 r.p.m. and has four forward speeds from 4 to 20 m.p.h. and a single reverse speed of 3 m.p.h. Its rolled steel joist chassis frame has pressed steel box section auxiliary members welded to it to form a rigid structure designed to withstand distortion and shock loading under bad working conditions. A pressed steel hopper has means of rapid gravity tipping with automatic return actuated by a single hand lever in the cab.

Drive from the engine is transmitted through a hydraulically controlled dry plate clutch to the gearbox, which is connected through a heavy universal coupling to a differential axle. Fully floating half shafts in this differential are connected by sprockets and chains to large sprockets on the tubular steel main driving axle mounted directly on the chassis.

The machine has a pressed steel box section steering axle, which is centrally pivoted to provide a four-point suspension and allow adequate free vertical movement of either wheel. No radius rods are fitted. Split track rod steering is effected from a centrally mounted mechanism, and all four wheels have servo-assisted hydraulic braking.

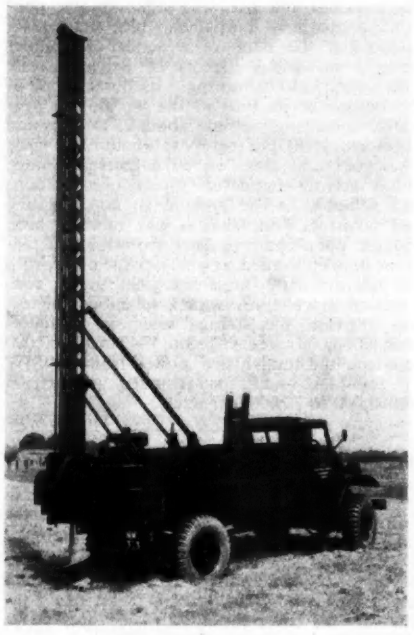
A towing hitch is provided at the front and at the rear of the machine, which has a draw-bar pull of 4000 lb in first gear.



Three-Cubic-Yard Dumper

A Soil Boring Machine

A SOIL boring machine which can be mounted on a lorry or trailer, as shown in the accompanying illustration, has been developed at the Road Research Laboratory; it will drill clean boreholes up to 20in in diameter and 16ft deep in most soils. The boring bar of this machine can be brought from travelling to working position in one minute and it will bore vertical or inclined holes at a rate of about 1ft a minute. Apart from making test bores when investigating sites for roads and buildings, it is pointed out the machine can also be used in place of a pile-driver when short piling is needed, such as in providing house foundations in clay soils.



Soil Boring Machine

The machine is a complete unit powered by its own air-cooled, twin-cylinder diesel engine developing 7 b.h.p. at 1200 r.p.m. Its hollow lattice mast is 9in square and can be raised from its sloping travelling position to a vertical position by means of a pair of feed screws controlled by a friction clutch. The main pivot is formed by trunnions mounted on the outside of a gearbox attached at the lower end of the mast.

The boring bar passes through a central square hole in a gearwheel which is driven by a second clutch. The bar slides through this gearwheel and is steadied at its upper end by a bearing which is free to slide inside the mast. The boring bar is attached to an endless chain which passes over a free sprocket at the top and a driving sprocket at the bottom of the mast. The bar is raised by power, but may be lowered either by power or by gravity, a hand-brake being used to control the feed. Driving shafts, for rotating and lifting, are arranged co-axially with the main pivots to permit boring with the mast inclined. A reversing gear gives change of direction to all the controlled motions. The normal speed of rotation of the boring tool is between 50–100 r.p.m. and the average lifting rate is approximately 3ft per second.

Three types of boring tools have so far been developed. The first has a circular plate welded to a vertical stem, the plate having two sectors removed and the leading edges bent down to give a slight lead. Separate cutting edges tipped with a hard material are provided for bolting to these leading edges. The sector openings are covered with hinged flaps which only allow the soil to pass upwards through the tool. This tool is satisfactory in most soils, but the cut-away portions will only allow small stones to pass through. To overcome this difficulty a second tool with a two-start helical form has been made. This tool is very suitable for large, loosely compacted gravels, but tends to ride over large stones if they are tightly embedded. A third tool was therefore designed to deal with such stones. It is fitted with two spikes about 4in long at about two-thirds of the radius out from the centre, and the circular path of these spikes loosens large stones which would otherwise not be disturbed.

Radiography in a Clyde Shipyard

A PAPER with the title "Radiography in a Clyde Shipyard" was presented by E. J. Duffy on Tuesday, November 18th, before the Institution of Engineers and Shipbuilders in Scotland and is summarised below.

When radiographic inspection units suitable for shipyard operation became available, the Clyde Shipbuilders' Association organised a scheme of inspection, on a regional basis, using three units, namely, a 90kV X-ray machine for plates up to ½in thick, a 140kV X-ray unit for plates up to 1½in thick, and a 250mg radium source for the examination of heavier sections. Each unit is controlled from a parent company and is available as required, but, as the extent of welding increases, it is expected that individual builders will acquire their own equipment. The paper describes the 90kV set and its work concerning welding within the parent firm, and discusses developments in radiographic inspection due to the availability of radioactive isotopes.

The principles of radiography are reviewed and in a note upon penetration the paper mentions that increase in voltage decreases the wavelength and increases the intensity and penetrative power of the beam. For examination purposes the film is placed behind the weld and the amount of radiation reaching it is dependent upon the absorption by the specimen, the amount of this being proportional to the atomic number density and thickness of the object. Where there is lack of continuity, such as poor root penetration, this is equivalent to a reduction in thickness and the radiation reaching the film is more intense, so that the processed film is denser at that point. The question of distortion is mentioned and the use of a step-wedge penetrameter is noted as a means of checking the quality of the radiograph.

The 90kV set, which weighs 1·5 cwt and is mounted on a trolley carrying a high-tension transformer and cables, X-ray tube head, and the control panel, is briefly described, and the principles of protection explained. In discussing routine weld inspection the paper stresses the importance of assessing the capabilities of individual welders by a series of test plates which should be radiographically examined, and a record kept. However, deficiencies in welding are not always the welder's fault, but can be attributed to faulty edge preparation; chisels ground to a shape to ensure a 60 deg. opening with a rounded root are recommended to overcome lack of root penetration in butt welds.

Due to the penetrative power of radium and radon radiation, gamma ray inspection has been limited to thicknesses over 2in, but with the

availability of radioactive isotopes, such as iridium 192, with its less penetrating radiation, a radiographic image of thinner plates can be recorded. Two other radioactive isotopes, cobalt 60 and tantalum 182, are available, but have properties similar to radium. Due to radioactive decay of the source, gamma-ray emission is constantly diminishing and such materials have a half-life period (which for iridium 192, is seventy days), during which activity falls by 50 per cent and then falls 50 per cent of the reduced activity in the second half-life period. Despite this, the maximum thickness it is possible to radiograph remains constant, but the time taken increases as the activity decreases. The isotopes can be returned for re-activation.

The curie or millicurie are stated to be the units for expressing the activity of an isotope, while the electron volt is a measure of its energy; gamma radiation having an energy of a million electron volts is approximately equivalent in penetration to an X-ray tube operating at 1000kV.

The significance of source size is touched upon and the paper goes on to discuss practical application of gamma radiation. A general description is given of the apparatus together with brief reference to exposure times and radiographic quality, followed by a note upon the need for accurate interpretation of radiographic findings.

India's Central Board of Irrigation and Power

(By our Indian Correspondent)

THE Central Board of Irrigation and Power, whose silver jubilee was inaugurated by the Prime Minister, Mr. Jawaharlal Nehru, in New Delhi on November 18th, owes its inception in 1927 to the constitutional changes effected by the Montague-Chelmsford reforms introduced after World War I. Prior to these reforms, irrigation, especially in its financial aspects, was a central subject, although its day-to-day administration was conducted by Provincial Governments. Later on, *circa* 1920, the financial responsibility was transferred from central to provincial hands, although, in theory, the Government of India continued to exercise powers of superintendence, direction and control. This somewhat complicated situation was resolved by the creation of the Central Board of Irrigation, which, as originally constituted in 1927 by the Secretary of State for India, was only a panel consisting of all the provincial chief engineers and the consulting engineer to the Government of India. The Board's main function was to examine a particular project or to report on any specific technical question on which advice might be required either by the Centre or a Provincial Government. This, however, scarcely altered the prevailing conditions under which the provinces worked in watertight compartments, duplicating work and often wasting labour and money on problems which had already been solved elsewhere. On the recommendation of the Royal Commission on Agriculture in India, the panel was enlarged to form an active committee to meet at intervals and to exchange views on common problems of interest, thus avoiding overlapping. Another organisation, the Central Bureau of Irrigation, was also constituted with the main function of establishing a library of irrigation publications, Indian and foreign, and acting as a clearing house for information needed by the provinces. Although, for a period, the Bureau and the Board worked separately, their functions complemented each other to such an extent that with effect from April 1, 1932, the Bureau was placed under the control of the Board and its functions and duties were defined as follows :—(1) To co-ordinate and guide research and bring about improvements in irrigation practice and methods of construction ; (2) to maintain a library, collect and disseminate knowledge on irrigation and allied subjects ; (3) to establish contacts with institutions and individuals both in India and abroad, in order to facilitate the exchange of publications and information ; (4) to provide liaison between provinces and personal contacts between officers engaged on similar work ; (5) to publish the results of research on irrigation and allied subjects ; (6) to contribute information on irrigation and allied subjects for publication in the Press.

Membership of the Board, originally limited to chief engineers of irrigation from the provinces, was extended to the more important princely States in 1940. In 1945 it was further thrown open to chief engineers (electricity) and senior officers of the Central Water Power, Irrigation and Navigation Commission and Central Electricity Commission—now Central Water and Power Commission. The ECAFE (Economic Commission for Asia and the Far East of the United Nations), the Railway Board and some Port Trusts and private firms in the country also now subscribe to the Board. The latest constitution of the Board was passed in 1951.

The Board works as the Indian National Committee for the International Commission on Large Dams and for the International Commission on Irrigation and Drainage. It also acts as the National Society in India for the International Society on Soil Mechanics and Foundation Engineering and as a liaison body for the International Association for Hydraulic Research and other international scientific organisations. It assists in the deliberations of several inter-departmental and technical organisations, publishes a quarterly journal and has, since 1947, undertaken the issue of a series of popular leaflets on various aspects of irrigation and hydro-electrical engineering. Its library, one of the biggest of its type in the world, has over 50,000 books and journals, about 2500 maps and drawings, 2000 photographs, about 250 trade catalogues and close on 60 engineering films. It has recently staged very successful exhibitions and symposia. The amount of co-ordinating and advising work that it has recently been engaged upon can be gauged from the fact that it has been concerned, one way or the other, with the nineteen dams, large and small, under construction since 1947, which, when completed, will augment the storage reservoir capacities from 8,000,000 acre-feet before 1947 to 90,000,000 acre-feet, the total hydro power from 500MW to 5500MW, and the irrigated area from 40,000,000 to 70,000,000 acres.

American Engineering News

(By Our American Correspondent)

Deep-Water Bridge Pier Foundations in the Hudson River

The New York State Thruway Authority has announced the award to the Merritt-Chapman and Scott Corporation, of New York, of a contract for the construction of fifteen deep-water bridge pier foundations for the Thruway bridge across the Hudson River between South Nyack and Tarrytown, New York. The construction of ten of the fifteen pier foundations will involve the unusual method of employing extremely large watertight boxes of reinforced concrete to provide a buoyant pier base resting on the silty river bottom. Surveys of the site have indicated that solid rock is too far below the surface at this particular point to be used effectively and economically for pier support, and the air-filled caisson design was developed to solve the problem. Two of the watertight foundation "boxes" will be 184ft long, 100ft wide and 40ft high, and will weigh approximately 16,000 tons. A further two will be 120ft long, 60ft wide and 40ft high. The remaining six will be of the same height, but slightly smaller in area. To construct the ten boxes the company will follow a procedure similar to the one it recently used in building, in a natural dry dock, three large substructure sections for the new Pier 57 in New York City. On completion, the foundation boxes will be towed to the bridge site, floated into exact position and then sunk into place above specially prepared gravel bases by filling them with water. When in position, the tops of the boxes will be approximately 2ft below the surface at mean low water. Piles will be driven to bed rock through wells in their walls to pin them permanently into place. As construction of the superstructure adds deadweight thrust on them, the water will be pumped from the boxes to restore the desired degree of buoyancy. The foundations for the five other piers to be constructed by the firm under the terms of the contract will be built within ten 35ft diameter circular steel sheet pile cofferdams, two for each double-legged pier. Work on the fifteen piers will begin at approximately midstream and follow an easterly line across the Hudson River for almost a mile.

Sinking of Central Valley Land in California

It has been determined that a 250 square mile area of the Central Valley in California has been gradually sinking during the last third of a century. The amount of settlement in various areas has been as much as 1ft to 8ft since 1920, according to a Bureau of Reclamation report, which has been compiled over the last several years. More detailed surveys will now be conducted to measure the exact extent of the land subsidence, and to ascertain its effect upon the operation and maintenance of the Central Valley Federal Reclamation project, which supplies irrigation water for more than one million acres of land in the Sacramento and San Joaquin River valleys. According to the report, the settling of land in the San Joaquin area is believed to have been brought about primarily by an excess pumping of ground water. There is a possibility, too, that recent earthquakes in the area may have resulted in a more rapid settlement. The area in question extends from the town of Pixley on the north to Famosa on the south, a distance of about 25 miles, and from Richgrove west to beyond Delano, a distance of 10 miles. In the critical area there are places where the land has settled 5ft within a distance of 3 to 4 miles. Indications are that the depression in the area has reached a maximum annual rate of about 9in. An area around and to the west of Mendota Pool, near the town of Mendota, has also been found to settle. The maximum subsidence in this area is situated 5 or 6 miles west of Mendota, where a depression of 8ft has been noted since 1920. It is felt that the settlement of Central Valley lands may create definite maintenance and repair problems for the Friant-Kern Canal of the Bureau of Reclamation, and, in limited areas, may affect the distribution systems. The report indicates that the Mendota Pool depression area probably will have a bearing on the ability of existing irrigation systems to get their water out of the Mendota Pool, and ultimately may have an effect on the capacities of the San Joaquin River and the Fresno Slough in connection with flood control schemes. Soil in the critical areas ultimately may not drain properly, especially in the case of large tracts of levelled farm land. The Bureau of Reclamation is continuing studies of this problem.

Explosion of a Hydrogen Weapon

The first hydrogen weapon has now been exploded by the United States, and the following is the official announcement released by the U.S. Atomic Energy Commission : "Joint Task Force 132, operating for the Department of Defence and the United States Atomic Energy Commission, has concluded the third series of weapons development tests at Eniwetok Atoll in the Marshall Islands. Like the "Greenhouse" series, 1951, it was designed to further the development of various kinds of weapons. In furtherance of the President's announcement of January 31, 1950, the test programme included experiments contributing to thermo-nuclear weapons research. Scientific executives for the tests have expressed satisfaction with the results. The leaders and members of the military and civilian components of the task force have accomplished a remarkable feat of precision in planning and operations and have the commendation of the Department of Defence and the Atomic Energy Commission. In the presence of threats to the peace of the world and in the absence of effective and enforceable arrangements for the control of armaments, the United States Government must continue its studies, looking toward the development of these vast energies for the defence of the free world. At the same time, this Government is pushing with wide and growing success its studies directed toward utilising these energies for the productive purposes of mankind."

Industrial and Labour Notes

"Attitudes to Productivity"

The British steel founding industry was the first to send from this country to the U.S.A. a productivity team under the ægis of the Anglo-American Council on Productivity. It will be recalled that the team's report was published in September, 1949. In the last three years or so the steel founding industry has gone a long way towards implementing the recommendations made in the report and productivity has been substantially increased. But it is realised that the efforts to gain the fullest measure of benefit from the recommendations have been, and still are, to some extent, frustrated by the partial failure of those who work in the industry to grasp that the consequences of failure to increase productivity are so grave as to demand the immediate abandonment of any attitude which constitutes an obstacle.

With this in mind, the British Steel Founders' Association has just held the third of its "productivity conventions," at which all concerned with management in the industry—from charge hand to managing director—met to consider the subject of "human attitude." The British Steel Founders' Association has now reported upon the discussions at the convention. It says that delegates were unanimous in their opinion that there is no substitute for good leadership, and that some were critical of British management for failing to select and train a new class of industrial leaders capable of dealing with modern problems, including that of personal relations. Consideration of the human attitude to productivity led the delegates to the conclusion that, so far as the British workman is concerned, the limits of purely monetary incentives are soon reached. It was agreed that it is essential to educate the British worker to an appreciation of the greater degree of comfort and enjoyment that increased productivity will bring within his reach.

One of the main conclusions agreed upon at the convention was that management must utilise the knowledge, experience and suggestions of employees at all levels and cultivate a more receptive attitude towards new ideas. It also agreed that all injustices existing in present incentive schemes must be removed immediately; in particular, the delegates decided, all established piecework rates must be regarded as sacrosanct while production processes remain unchanged. To that they added that equipment should be improved wherever possible to promote the comfort and safety of operatives. Another conclusion reached was that the problem of productivity is one for industrial management and is not a trade union responsibility. On the other hand, it was noted, trade unions have so far failed to realise that restrictive practices based upon out-of-date fears and prejudices are seriously retarding productivity. All restrictive practices, whether on the part of management or operatives, were condemned by those present at the convention. There was a good deal of criticism of the frustrating practice of rate-cutting by management and of the arbitrary restrictions on the upgrading of semi-skilled labour and schemes for adult apprenticeship imposed by the unions.

Training for Management

In the course of his speech at the annual meeting of Crompton Parkinson, Ltd., which was held on December 12th, the chairman, Mr. Albert Parkinson, referred to the company's various schemes for management training. He said that recently the company had initiated two new schemes. One was a plan to train for particular jobs by the careful selection of a limited number of promising young men for special "on the job" training, designed to develop those skills, increase that special knowledge, and provide the particular experience that were required for the job in question. The other scheme was a more general one for training in the problems attached to particular products. That training was given in each case by the appointment of selected persons to a special committee which, under experienced chairmanship, was encouraged to discuss and make recommendations concerning the product, its development, manufacture, and sale. Experience to date, Mr. Parkinson said, encouraged the company to believe that those schemes would prove to be successful.

British Overseas Trade

Provisional figures relating to the United Kingdom's overseas trade in November, which were issued at the end of last week by the Board of Trade, give the value of exports of United Kingdom goods as £207,200,000. Although this is lower than the recorded value of October exports—which was £218,800,000—the daily rate of export in November was 2 per cent higher than in October, there being only twenty-five working days in November as against twenty-seven in October. If the two months are taken together, however, the monthly average was £213,000,000, compared with a monthly average of £191,300,000 in the third quarter. Thus, the October-November average was an increase of about 11 per cent over the third quarter, but was still below the monthly average of £224,400,000 for the first half of this year. Imports into the United Kingdom during November have been valued provisionally at £261,800,000, compared with £266,600,000 in October, and with a monthly average of £262,600,000 in the third quarter of this year. The total value of imports in the first eleven months of this year, January to November, was £3,218 million, compared with £3,603 million in the corresponding period of last year. Re-exports in November have been valued at £8,900,000, so that the excess of imports (c.i.f.) over exports and re-exports (f.o.b.) was £45,700,000, compared with £35,700,000 in October and £61,100,000 a month in the third quarter of this year.

The Commonwealth Economic Conference

The Commonwealth Economic Conference in London was concluded on Thursday of last week, December 11th, and on the same day there was issued by the Treasury a general report surveying the discussions which have taken place. The conference was convened with the aim of concerting measures for increasing the economic strength of the Commonwealth countries, including the Colonial territories, and for creating conditions in which the peoples of those countries can play their part in securing prosperity and contentment for themselves and for the world.

The Conference agreed that the Commonwealth countries would work together to achieve certain broad objectives. The Treasury's report says that the principles decided upon as governing the approach to the subjects discussed were that internal economic policies designed to curb inflation and rises in the cost of living should be steadily followed; that sound economic development should be encouraged with the object of increasing productive strength and competitive power, providing employment and raising the standards of life; and that a multi-lateral trade and payment system should be extended over the widest possible area.

On the subject of development policy, the report says that throughout the Commonwealth there is wide scope for expanding the production of the essential supplies which the whole world needs—food and agricultural products, minerals and engineering products—and improving the means for transporting them. This development of the basic essentials has been impeded on occasion by other development of a less sound and permanent nature which has overtaxed the countries' resources and has failed to contribute to the building of economic strength. The Conference therefore agreed that in sterling area countries development should be concentrated upon projects which directly or indirectly contribute to the improvement of the area's balance of payments with the rest of the world. Such projects should strengthen the economies of the countries concerned and increase their competitive power in world markets. The report goes on the say that the United Kingdom is the traditional source of external capital for Commonwealth investment and has special responsibilities in the Colonial territories. The United Kingdom Government is determined that the flow of capital from London for sound development throughout the Commonwealth shall be maintained and increased. But, it is observed, that will only be possible if the United Kingdom can sustain the necessary level of internal savings and can achieve a surplus on overseas account additional to that required to meet its heavy existing commitments.

Health and Safety of Foundry Workers

The Foundry Workers (Health and Safety) Bill—which is a Private Members' Bill—was given a second reading in the House of Commons and committed to a standing committee on Friday last. Its second reading was moved by Miss Margaret Herbison, who suggested that, since 1947, the findings and recommendations of the Garrett Report had not been implemented to anything like the extent that even the most reasonable people had had the right to expect. At the same time, Miss Herbison agreed that it would be completely wrong to say that nothing had been done as a result of the report. To give that impression, she said, would be doing less than justice to many good employers. Miss Herbison went on to claim that the accident rate amongst foundry workers was, on the average, three times greater than that for all workers of this country. The Bill had been designed to cut down the number of accidents.

The debate on the motion for the second reading was wound up by the Parliamentary Secretary to the Ministry of Labour, Mr. Harold Watkinson. He emphasised that there was not a reasonably practical suggestion in the Bill that could not be covered by regulations under the existing Factories Acts. The main purpose of the Bill, he assumed, was to emphasise that Parliament or the Government had been too slow in enacting the provisions of the Garrett Report. The Minister of Labour, Mr. Watkinson said, would be pleased to have a further demand from the trade unions for more consultations on how the recommendations of the Garrett Report could be implemented as quickly as possible.

Strike of Colliery Winders

An unofficial strike of colliery winders in the Yorkshire coalfield began last Saturday over a demand to the divisional coal board for a pay increase of 3s. a shift. On Monday it was stated that seventy-six pits were affected by the strike, but that in spite of the strike, twenty-four of the pits had managed to maintain their normal production. In answer to a question in Parliament on Monday afternoon, the Minister of Labour, Sir Walter Monckton, Q.C., said that the men concerned in the strike were members of the Yorkshire Winding Enginemen's Association, which was a constituent part of the National Union of Mineworkers. The latter body was the sole union recognised by the National Coal Board for negotiating purposes in relation to winding engine men. The union, Sir Walter continued, did not support the unconstitutional action taken by the winders, and it was collaborating with the National Coal Board in measures which had been taken to minimise loss of production. If continued, Sir Walter added, the strike could only cause unjustifiable loss to the community at large and inflict unnecessary hardship on the men themselves, on their families, and on thousands of their fellow workers in the pits at a season when such hardship was peculiarly hard to bear. He therefore urged the men concerned to stand by the agreements of the industry to which they were parties, and to return to work without delay.

Notes and Memoranda

Rail and Road

TRAM TRACK.—The Parliamentary Secretary to the Ministry of Transport, Mr. Braithwaite, has stated that at the end of the war there were about 185 miles of tram track in the Administrative County of London. To date, about 60 miles have been removed, the weight of scrap metal recovered being 17,892 tons, valued, at current controlled prices, at about £125,000.

THE KINGSWAY TUNNEL.—In a written reply made this week, the Minister of Transport, Mr. Lennox-Boyd, says that he has now considered the report of the technical committee on the Kingsway (London) tram subway. After examining various alternatives, the committee has concluded that if the subway were to be used for traffic the most satisfactory scheme would cost about £1,200,000. The Minister's reply adds that the likely advantages of this adaptation, or indeed of any other alternative scheme, do not seem to be commensurate with the cost.

Air and Water

I.N.A. SCHOLARSHIPS.—The council of the Institution of Naval Architects announces that it has decided to raise the age limit for the Trewent Scholarship in Naval Architecture to "under twenty" instead of "under nineteen."

OIL DRILLING BARGE.—The diesel-electric power barge which was built by Ferguson Brothers (Port Glasgow), Ltd., for the Shell Petroleum Company, Ltd., and left the Clyde under tow in October is nearly at Lake Maracaibo, where the craft will be used for oil drilling operations.

CLYDE RIVER FLEET.—Next summer British Railways (Scottish Region) expects to commission four twin-screw passenger ships on the Clyde coast services as part of the scheme to modernise the Clyde Fleet. Towards the end of 1953 a further three vessels are expected to be completed; these will be general-purpose ships carrying passengers, vehicles and cargo.

COASTAL MINESWEEPER.—Her Majesty's Coastal Minesweeper "Burnaston," was launched yesterday from Fleetlands Shipyard, Ltd., Gosport. The vessel, which will be armed with three small guns, has a length of 152ft by 28ft 9in beam, and has a skin of wooden planking laid over aluminium alloy frames. The main machinery will be supplied by Mirrlees, Bickerton and Day, Ltd., Stockport.

ELECTRONIC MEGAPHONE.—A new voice amplifier has been placed on the market by the Special Products Division (MIMCO) of the Marconi International Marine Communication Company, Ltd. Named "Jericho," the megaphone gives distortion-free amplification of the voice audible up to 500 yards. It weighs 7 lb 4 oz complete with four small dry batteries, and is carefully balanced so that it can be used for long periods without fatigue. No valves are used and the use of dry batteries means that acid batteries and trailing wires are obviated.

AIRWORTHINESS CERTIFICATES FOR PRIVATE AIRCRAFT.—The Ministry of Civil Aviation says that for aircraft not exceeding an all-up weight of 3500 lb certified solely as private, certificates of airworthiness in future can be made valid for three years (instead of one, as at present) on the following conditions:—The aircraft must be inspected and maintained in accordance with a schedule approved by the Air Registration Board; the inspection and maintenance must be certified by a licensed aircraft maintenance engineer employed by an approved firm or flying club; and records of inspection and maintenance are to be made in the aircraft and engine log books and shown to the Air Registration Board when the certificate of airworthiness comes up for renewal.

Miscellanea

"THE STABILIZER."—We are informed by the Lincoln Electric Company, Ltd., of Welwyn Garden City, Herts, that the house journal of its American associate company is now being printed in this country. This journal, called *The Stabilizer*, contains articles on welding work in general and discusses welders' problems. It is published bi-monthly and issued free of charge.

ELECTRODES FOR MANGANESE STEEL.—We are informed that the Quasi-Arc Company, Ltd., is now making a new form of its "Manganoid" electrode, which is used for the welding of 12/14 per cent austenitic manganese steel. The new type electrode deposits crack-resisting weld metal which work hardens rapidly to provide maximum resistance to wear, impact and abrasion.

TRANSFORMER FOR BRITISH 275kV GRID.—The first transformer for Britain's 275kV grid was completed at the English Electric Company's Stafford works. It is a three-phase auto-connected unit with a voltage ratio of 275/132kV and a rating of 120MVA. The peak values of the impulse test were 1050kV for the full wave and 1200kV for the chopped wave. The wound core will be transported to the site in the tank, without oil, the weight being 87 tons.

CONFERENCE ON TROPICAL ARCHITECTURE.—A conference on tropical architecture is to be held at University College, London, from March 23 to March 27, 1953. It has been arranged with the support of the Colonial Office and the Royal Institute of British Architects, and the papers to be presented include amongst their subjects building materials and techniques and indoor "climates." Further details may be obtained from the secretary of the conference, University College, London, W.C.1.

IRON AND STEEL DEVELOPMENT SCHEMES.—A written parliamentary reply by the Minister of Supply says that schemes proposed by forty-six steel companies, at an estimated cost of about £151,000,000, have been approved by the Iron and Steel Corporation of Great Britain. The schemes relate mainly to the construction of coke ovens, blast-furnaces, steelmaking plant, and steel rolling and finishing plant, together with associated ancillary plant and services.

SPHEROIDAL-GRAPHITE CAST IRON.—A recent publication of the Mond Nickel Company, Ltd., Sunderland House, Curzon Street, London, W.1, deals with the engineering properties and applications of spheroidal-graphite cast iron. Following a brief introduction, the publication deals in some detail with the two main types of spheroidal-graphite cast iron, its properties, specifications, production characteristics, modifications, working, service properties, applications, &c.

MR. W. F. KENT.—We regret to announce the death, on December 9th, of Mr. Wilfred Francis Kent, contracts manager of the Marconi International Marine Communication Company, Ltd. A native of Borrisokane, Co. Tipperary, Mr. Kent joined Marconi's Wireless Telegraph Company, Ltd., in 1913. He served throughout the 1914–18 war as a signals officer in the Royal Engineers in France, the Dardanelles and Russia. In 1924 he rejoined the company and represented its interests in Turkey and Bulgaria. In 1937 he became contracts manager of the company's small craft division.

FIFTY YEARS OF OIL.—A brochure entitled "Fifty Years of Oil," has been issued by the Anglo-Iranian Oil Company and surveys the progress made by the company through the first half of this century. A short history traces developments from the 1901 concession given to Mr. W. K. D'Arcy through two world wars up to cessation of operations in 1951, by which time the annual capacity had risen from 400,000 tons to 32,000,000 tons. A map indicates the worldwide interests of the company and there are notes upon the various refineries followed by brief references to shipping, marketing and research activities.

PORTO MARGHERA REFINERY.—A new thermal reforming unit to process 300,000 tons per annum of naphtha and produce high octane motor spirit component has been completed and is now in operation at the Porto Marghera refinery, Venice, which is owned jointly by the Anglo-Iranian Oil Company, Ltd., and the Agienda Generale Italiana Petroli. The refinery capacity has been raised to about 1,500,000 tons a year by the increased yield of motor spirit amounting to 280,000 tons per annum which will be increased further when a catalytic polymerisation unit, to handle gases from the thermal reformer, comes on stream next year.

VIBRATION AND NOISE ISOLATION.—An interesting brochure describing the methods it has developed for the isolation of vibration and noise has just been issued by W. Christie and Grey, Ltd., of 4, Lloyd's Avenue, London, E.C.3. This firm has for many years specialised in this particular subject, which has become of increasing importance as the amount of machinery and power plant used in buildings has grown. The brochure deals in a clear, concise way with vibration principles and various forms of isolation, together with materials and equipment for special applications. The information given is well supplemented with photographs and diagrams.

NORTHAMPTON POLYTECHNIC LECTURES.—Two courses of special lectures have been arranged for the New Year at the Northampton Polytechnic, St. John Street, London, E.C.1. The first course, consisting of eight lectures by Mr. G. F. J. Murray, B.Sc., A.M.I.C.E., is on "Liquid Fuels, their Properties and Utilisation." The lectures will be given on Tuesday evenings at 7.30 p.m., beginning January 6th. The subject of the other course of lectures is "Chemical and Metallurgical Thermodynamics." This course also consists of eight lectures, which will be delivered by Dr. O. Kubaschewski, on Wednesday evenings at 7.30 p.m., beginning on January 7th. The fee for each lecture course is £1.

SYMPOSIUM ON NUCLEAR REACTOR INSTRUMENTATION.—The Institution of Electrical Engineers is to hold a symposium on nuclear reactor instrumentation in the Institution lecture theatre on January 8, 1953. Sir John Cockcroft will give a lecture at 4.30 p.m. on "Nuclear Reactors and Applications." The second session, at 6 p.m., will consist of the reading and discussion of three papers: "The Control of a Thermal Neutron Reactor," by R. V. Moore; "Automatic Control Characteristics of Thermal Neutron Reactors," by J. H. Bowen; and "Neutron Detectors for Reactor Instrumentation," by T. A. J. Jaques, H. A. Ballinger and F. Wade. A brief synopsis of the lecture and copies of the three papers will be obtainable from the Secretary of the Institution towards the end of this month.

A NEW FILM ON STEEL TUBE MAKING.—There was shown in London last week for the first time a new film made for Stewarts and Lloyds, Ltd., dealing with the manufacture of steel tubes by the electric resistance welding process at Corby. This process was described in detail in our issue of July 18th last. The film first briefly touches upon the making of steel and strip and then step-by-step follows the complete process of making tubes by resistance electric welding, concluding with a number of applications to which the tubes are put. In addition to this film there was also shown one telling the story of the design and construction of the massive tubular steel jib fitted to the "W.1400" walking dragline now in operation at the Stewarts and Lloyds ironstone quarries. Each of these films is an impressive and interesting record of industrial achievement and enterprise, and in each of them excellent photography is combined with an effective running commentary.

LAND BOILERS.—We have received from Yarrow and Co., Ltd., of Glasgow, a copy of the company's illustrated brochure entitled "Yarrow Land Boilers." A diagram shows eight arrangements of Yarrow boilers, and then there is a general description of the boiler the first unit of which was erected in 1922, with brief notes upon the main items. Pulverised fuel is mentioned in connection with a "SF1/2 S.D." boiler, of which a typical layout drawing is included, and then, following a note upon maintenance, is a description of the methods of manufacture and erection, together with references to inspection, testing and research. Representative installations for power stations and works are described and illustrated with line drawings, and a list gives some of the companies, throughout the world, which use Yarrow land boilers.

FIVE OIL FILMS.—On Wednesday of last week, the Anglo-Iranian Oil Company, Ltd., showed five films, depicting various aspects of the oil industry at a number of London cinemas. "Oil for the Twentieth Century" was the title of the first film, which, with a running time of thirty minutes, traced the history and growth of the company from 1901 to 1951, and showed the pioneer work of W. K. D'Arcy in the search for oil linked with the rapid development of the oil engine as a source of power. A ten-minute cartoon in Technicolour, followed, and this film, entitled "We've Come a Long Way," which won the 1951 Venice Film Festival award, showed the development of the oil tanker from the early sailing brig of 1861. Awarded first prize at the 1952 Venice Film Festival, the film "Rig 20" told of the battle waged against a serious oil well fire which occurred at Naft Safid in 1951. The fourth film, "Persian Story," which was in Technicolour, ran for twenty minutes and gave a general review of the oilfields, Abadan and of the life led by the company's British and Persian employees. A ten-minute film, "A Moment in Time," was the last to be shown, and recorded an impression of the many and varied activities of the Anglo-Iranian Oil Company, Ltd., throughout the world.

Personal and Business

MR. H. N. NORBURY has been appointed sales manager of Henry Meadows, Ltd., Wolverhampton.

ENFIELD CABLES, Ltd., announces that Mr. J. Birkbeck has been appointed production manager of Brynmawr Rubber, Ltd.

FOUNDRY SERVICES, Ltd., Long Acre, Nechells, Birmingham, 7, states that its telephone number has been changed to East 1911.

E. AND L. B. PINKNEY, Ltd., Middlesbrough, states that it has opened a London office at 120, Victoria Street, S.W.1 (telephone, Victoria 3670).

THE VACUUM OIL COMPANY, Ltd., announces that Mr. B. R. Fraser, B.Sc., has been appointed assistant manager of the company's Coryton refinery.

VICKERS-ARMSTRONGS, Ltd., states that it has acquired the sole right to manufacture and sell the equipment hitherto supplied by Hyland, Ltd., Wakefield.

ROBERT HUDSON, Ltd., Leeds, states that its London office is now at 47, Victoria Street, S.W.1 (telephone, Abbey 7127; telegrams, "Raletrux, Sowest, London").

BRUCE PEEBLES AND CO., Ltd., Edinburgh, 5, announces that its works will close for the New Year holiday on Wednesday, December 31st, and will reopen on Tuesday, January 6th.

THE BRUSH A.B.O.E. GROUP announces the appointment of Mr. D. G. Hawkins as general manager of the National Gas and Oil Engine Company, Ltd., Ashton-under-Lyne.

MURAD DEVELOPMENTS, Ltd., Stocklake, Aylesbury, Bucks, states that Mr. F. A. S. Gilmore has been appointed its sales engineer in the Birmingham and Coventry area.

W. C. YOUNGMAN, Ltd., Manor Royal, Crawley, Sussex, announces the appointment of Mr. E. T. Adams as technical representative in the Midlands area of its materials handling equipment division.

MR. A. G. DENNIS has been appointed chairman, and Mr. H. V. Yorke and Mr. C. Norman Baker have been elected directors of R. H. Windsor, Ltd., Chessington, Surrey. Mr. R. E. G. Windsor continues as managing director of the company.

SIR PERCY LISTER, chairman of R. A. Lister and Co., Ltd., has announced that Mr. M. I. Prichard, Mr. F. E. Blackstone and Mr. C. D. MacQuaide have been invited to be assistant directors of the parent company. They are members of the executive staff of the Lister group.

THE NEW ZEALAND SHIPPING COMPANY, Ltd., and the Federal Steam Navigation Company, Ltd., announces that, owing to ill health, Mr. H. W. S. Whitehouse will retire at the end of the year and will be succeeded as chairman and managing director by Mr. F. E. Harmer, C.M.G., the deputy chairman.

THE ROYAL MAIL LINES, Ltd., announces the election of Sir E. Murrant as deputy chairman and the retirement of Mr. C. C. Barber, who will be succeeded as managing director by Mr. A. Lawrence, the present general manager and a director. Two additional directors have been appointed, Mr. A. Wright and Mr. C. W. Varney.

MR. S. J. HARLEY, M.I.Mech.E., and Major G. W. Moore, chairman and deputy chairman respectively of the Coventry Gauge and Tool Company, Ltd., have been appointed to the board of the Pitter Gauge and Precision Tool Company, Ltd. Mr. Harley has been elected chairman of Pitter Gauge and Precision Tool Company, Ltd., in succession to Brigadier General R. F. Legge, who remains a director of the company.

British Patent Specifications

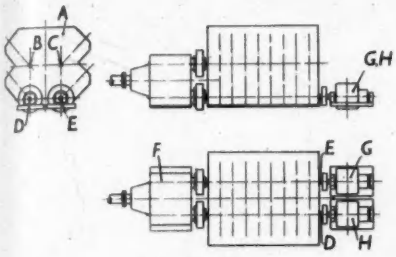
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

MARINE ENGINEERING

682,881. December 29, 1949.—Marine Power Plant, Société D'Etudes de Machines Thermiques, 7, rue Auber, Paris, France.

In the arrangement shown in the drawings the multi-crankshaft diesel engine *A* has four crankshafts *B*, *C*, *D* and *E*. The upper crankshafts *B* and *C* are driven by twin banks of cylinder and piston units in V arrangement, while the lowermost crankshafts *D* and *E*, which are in the same horizontal plane, are



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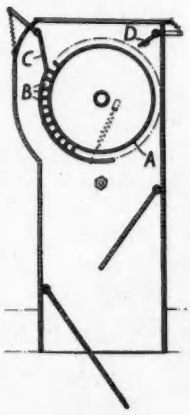
driven by single banks of such units. The crankshafts are coupled at the after end through clutches with a speed reduction gear *F*, driving the propeller shaft. The two lower crankshafts *D* and *E* are provided at the forward end with clutches of any suitable kind, through which they are coupled with electric generators *G* and *H*, operable independently of each other. It will be seen that when it is required to produce electric power, one or both of the after clutches can be disengaged and the corresponding forward clutch engaged, whereupon one or both of the generators can be put into operation as required.—*November* 19, 1952.

FURNACES

682,929. May 11, 1951.—Feeding Devices for Breeze Fuels, David Leonard Swendsen, Bergsgatan 86, Gävle, Sweden.

In the drawing the feeding drum *A* is mounted in the upper part of a shaft and has pockets *B* around its periphery. The drum is mounted close to one side on a horizontal shaft, the opposite side wall of the shaft being bent out to allow large fuel pieces to pass. In order to allow the drum to feed only that fuel quantity which is determined by the size of the pockets and the number of revolutions, it has a scraping plate *C* set against the drum. The scraping plate is hinged and spring loaded at each end. For obtaining a uniform feeding of the fuel delivered from the drum the lower free end of the scraping plate is cut off obliquely. A spring-operated scraping plate *D* at the shaft wall opposite to the scraping plate prevents the fuel from falling down at this side of the shaft.—*November* 19, 1952.

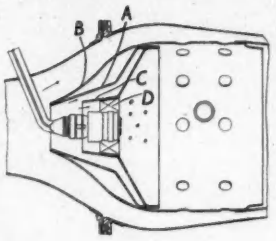


No. 682,929

GAS TURBINES

682,778. October 27, 1949.—Combustion Chambers for Prime Movers, Joseph Lucas, Ltd., of Great King Street, Birmingham, 19 (*Inventors: John Stanley Clarke, William Edmund Gregory*).

This invention relates to combustion chambers, for jet engines, gas turbines or other prime movers, and the object is to minimise energy loss by turbulence in the two parts of the air stream at the approaches to the jacket and combustion chamber. According to the invention there is arranged in the air jacket and at a position outside the entrance end wall of the combustion space an annular partition which divides the incoming air stream into two parts, one of which is directed into the jacket and the other to the combustion chamber. It comprises inner and outer sheet metal parts *A* and *B*. The inner part is shaped to correspond with the adjacent portion *C* of the combustion chamber, and the outer part is shaped to correspond with the adjacent part of the air jacket enclosure. The entrance to the axial region of the combustion hamber is preferably shaped to form a short tapering duct *D* leading to the air swirling means, so dividing the combustion chamber air



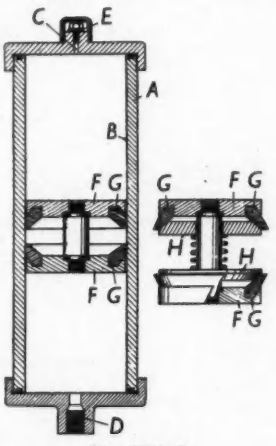
No. 682,778

stream into two parts, one of which flows through the duct, and the other along the passage between the duct and the inner surface *A* of the partition to the perforated end wall of the combustion space. A modified construction is also shown in the specification.—*November* 19, 1952.

HYDRAULIC MACHINERY

682,825. November 24, 1950.—Gas and Liquid Separating Pistons and Hydraulic Accumulators, Jean Louis Gratzmuller, 30, Avenue Georges Mandel, Paris 16e, Seine, France.

As shown in the drawings, a hydraulic accumulator operating with oil and compressed air or gas comprises a body *A* with a cylindrical bore *B* closed at both ends, an air or gas port *C* being provided in one end and an oil port *D* in the other. The port *C* is closed by a plug *E* protected by a cap, which may be removed and replaced by a conventional inflating head which permits unscrewing of the plug after



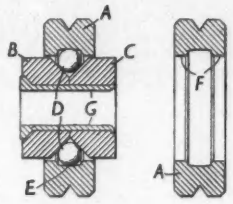
No. 682,825

having connected the accumulator with a source of pressure gas and screwing the plug up again without breaking this connection. The accumulator piston, more clearly shown in the right-hand view, has two rigid heads or discs *F*, each of which carries a packing *G*. Discs *F* are connected by a rod; an annular hollow space being provided between the discs. The device may be completed by means for applying the lips of the packings against the cylinder wall by two washers *H*, each of which is pressed upon one of the packings by a helical spring between the washers. The packings *G* are so designed that they allow the oil to penetrate into while preventing it from escaping from the hollow space.—*November* 19, 1952.

BEARINGS AND SUPPORTS

682,531. February 24, 1950.—Ball Bearings, J. Collis and Sons, Ltd., 42 and 43, Regent Square, Gray's Inn Road, London, W.C.1. (*Inventor: Leslie Alfred Collis.*)

The invention relates to ball bearings, more particularly for non-precision work, such as roiler conveyors. Referring to the drawings, the bearing is intended to function mainly as a journal bearing and comprises an outer race *A*, an inner race *B* and *C*, and balls *D*, between the races. The diameter of the main journal bearing surface *E* is larger than the diameter of the circle of the contact points of the balls to give a certain amount of clearance between the balls and the surface. The side bearing surface is also flanked on either side by inwardly projecting peripheral flanges *F*, the inner edges of which are preferably chamfered parallel, or substantially parallel, to the opposing cones. The inner race is formed of two truncated cone members *B* and *C* and which are mounted apex to apex on a central sleeve *G*. One end of the sleeve is provided with a countersunk head in a corresponding recess in the end of one



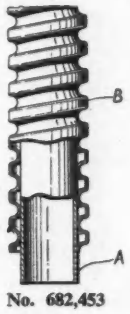
No. 682,531

of the cones and the inner race is completed by spinning over the other end of the sleeve after the balls have been inserted.—*November* 12, 1952.

MISCELLANEOUS

682,453. November 16, 1949.—Screw-Threaded Rods, Essex Aero, Ltd., and Reginald Jack Cross, both of London East Airport, Gravesend, Kent.

The invention relates to improvements in the manufacture of male screw-threaded members such as are required where light weight and cheapness of production are primary considerations. One form of construction is shown in the drawing. The tubular core *A* is formed from a light metal alloy and the swaged helical component *B* from carbon steel cold drawn seamless tube. The two parts are fixed together throughout their length by sweating. In this way the bottom of every thread is firmly secured to the core so that any compressive or tensile loads applied are distributed in the tubular core. A screw-threaded member manufactured in the manner described is especially suitable for use in the fabrication of the male threaded members of screw-jacks required for use where weight must be kept to a minimum.—*November* 12, 1952.

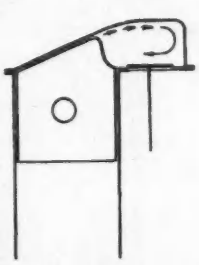


No. 682,453

INTERNAL COMBUSTION ENGINES

682,341. June 7, 1950.—Internal Combustion Engines, Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany.

The invention relates to an internal combustion engine with a compression space which is formed entirely in the cylinder head and projects laterally beyond the periphery of the cylinder to serve also as a valve chamber, particularly for valves controlled from below. As can be seen in the drawing, the upper wall of the compression space is connected tangentially, without any step or recess, to the upper sloping wall bounding the cylinder space. The piston has an inclined head shaped to conform to the wall, so that the air enclosed is displaced almost completely into the compression space or valve chamber. On the side towards the compression space, the piston has a recess of straight or curved shape, which gives as undisturbed as possible an eddy form in the compression space in the upper dead-centre position. During the largest portion of the compression stroke, the compressed air, or the compressed mixture, flows in the direction of the arrow from the cylinder space over into the compression space where it forms an eddy, as shown, which is maintained until the end of the compression stroke and near the upper dead-centre point. The air, or the mixture, is guided between the cylinder space and the compression space without its direction being reversed and, as far as possible, in conformity with its direction of flow, so that the eddies can develop in a particularly effective fashion. At the same time, a large open cross-section is provided for flow between the two spaces, which allows of practically unthrottled, loss-free, flow of air, or mixture, from the valve chamber into the cylinder space and, consequently, ensures a high degree of charging of the engine. The compression ratio can, therefore, also be made comparatively high.—*November* 5, 1952.

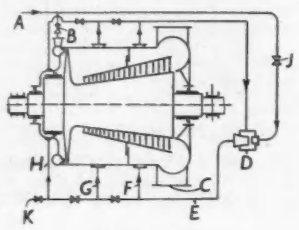


No. 682,341

STEAM AND GAS TURBINES

682,568. February 1, 1951.—THE STARTING OF TURBINES, Karl Andreas Röder, 13a, Post Rottendorf, near Würzberg. Germany.

The invention has for its object to equalise the temperature between the upper and lower parts of the turbine so that differences in temperature are avoided when the turbine is to be started. As the



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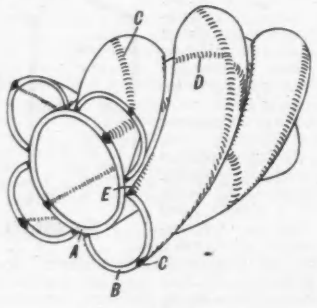
drawing shows, high-pressure steam is supplied to the turbine by the conduit *A* through a main valve *B*, and after expansion in the stages of the turbine, leaves the casing at *C*. For heating up the turbine before starting takes place, an ejector *D* is provided with its supply side connected to the conduit *A* at the upstream side of the valve *B*. The outlet side of ejector by means of a conduit *E* and branch pipes *F*, *G* and *H* is connected to openings provided at suitable places in the lower part of the wall of the casing. The suction side of the ejector, by means of a main and similar branch pipes, is connected to suitable openings provided in the upper part of the wall of the casing. Before starting, the turbine valve *J* is opened, the main valve *B* of the turbine still remaining closed. Hot fluid under pressure enters the ejector and is discharged into the lower part of the casing of the turbine, so that an ascending flow of hot fluid tends to equalise the temperature in all parts. Temperature differences between the upper part and lower part of the turbine are avoided. Bending of the rotor shaft and the axis of the casing caused by differences in temperature between the upper and lower part of the casing are prevented. The water condensate may be withdrawn at *K*. Part of the hot fluid under pressure supplied by the ejector is discharged through the exhaust *C*. When normal operation of the turbine is required, the main valve is opened and valve *J* is closed. Only normal deflections of the turbine shaft and the casing can then occur, so that distortion and damage of the labyrinth or stuffing-boxes and blades are avoided.—*November* 12, 1952.

COMPRESSORS AND BLOWERS

682,099. March 16, 1950.—MANUFACTURE OF ROTORS FOR ROTARY GAS COMPRESSORS AND MOTORS, James Howden and Co., Ltd., and Per Helge Natanael Ulander, both of the company's address, 195, Scotland Street, Glasgow, C.5.

This invention relates to a method of manufacturing lobed rotors for rotary gas compressors and motors, which consists in welding a set of metal pressings constituting lobes to a tubular hub, and attaching stub axles to the ends of the hub. The



No. 682,099

drawing shows a perspective view of a male rotor having helical lobes before the stub axles are attached. *A* is a tubular hub and *B* are metal pressings forming the lobes of the male rotor, the lobes being formed in several sections welded together longitudinally at *C* and transversely at *D*, the lobes being welded to the hub at *E*. The specification describes the construction of female rotors and the provision of cooling passages, and also the welding in of the stub axles.—*November* 5, 1952.

Launches and Trial Trips

KARAMU, motor coaster; built by Henry Robb, Ltd., for the Union Steam Ship Company, of New Zealand, Ltd.; length between perpendiculars 250ft, breadth moulded to upper deck 17ft 9in, deadweight 2100 tons on 16ft draught; designed speed 11 knots; three 114kW diesel generators; Clark-Sulzer TPD 48, two-stroke diesel engine, five cylinders, 1500 b.h.p. at 225 r.p.m. Launch, December 2nd.

MAAMAL, harbour tug; built by the Fairmile Construction Company, Ltd., for the Aden Port Trust; length between perpendiculars 55ft, breadth 15ft. depth 7ft 10½in., displacement 68 tons, speed running free 9 knots, static pull 4·1 tons, Kort nozzle; Blackstone EVMGR/6 six-cylinder diesel engine, 270 b.hp. at 600 r.p.m. Trial, November.

WAIMEA, cargo liner; built by Alexander Stephen and Sons, Ltd., for the Union Steam Ship Company of New Zealand, Ltd.; length 325ft, breadth 50ft, depth 26ft, deadweight 5100 tons; electric deck machinery, three 135kW diesel generators; Stephen-Sulzer single-acting diesel engine, six cylinders, 600mm diameter by 1040mm stroke, 2410 b.h.p. at 128 r.p.m. Launch, December 1st.

BEAVERBANK, cargo liner; built by Harland and Wolff, Ltd., for the Andrew Weir Shipping and Trading Company, Ltd.; length between perpendiculars 425ft, breadth moulded 59ft, depth moulded to shelter deck 38ft 3in, gross tonnage 5800; Harland-B. and W. two-stroke, single-acting, opposed-piston diesel engine, six cylinders 620mm diameter by 1870mm combined stroke, three 175kW diesel generators. Launch, December 3rd.

LEOPOLD L.D., cargo liner; built by Ateliers et Chantiers de la Loire for Armement Louis Dreyfus; length between perpendiculars 452ft 9in, breadth moulded 60ft 1in, depth to shelter deck 37ft 10in; deadweight 9350 tons, loaded draught 25ft 8in, service speed 14·75 knots; Sulzer single-acting, two-stroke diesel engine, 5600 b.h.p. at 125 r.p.m., three 275kW diesel generators. Trial, November.

Contracts

THE ANGLO-IRANIAN OIL COMPANY, Ltd., has placed a contract with K. L. Kalis Sons and Co., Ltd., Stone House, Bishopsgate, London, E.C.2, and the Dredging and Construction Company, Ltd., of King's Lynn, for extensive dredging and land reclamation work in connection with the new oil port at Aden. It is expected that work on the site will begin at the end of January, 1953. The consulting engineers are Messrs. Rendel, Palmer and Tritton, London.

DURING the past month, the British Electricity Authority has placed contracts for equipment for power stations, transforming stations and transmission lines amounting in the aggregate to £4,794,244. The principal contracts include: Cowes power station, foundations and river works (J. Croad, Ltd.); Castle Donington power station, near Derby, c.w. valves (J. Blakeborough and Sons, Ltd.), and c.w. pumps (Worthington-Simpson, Ltd.); Ince power station, near Ellesmere Port, four cooling towers (Film Cooling Towers (1925), Ltd.); Dolgarrog power station, Caernarvonshire, 33kV switchgear (Ferguson Pailin, Ltd.); Wakefield power station, main civil engineering works (Mitchell Construction Co.), and six boiler feed pumps (Mather and Platt, Ltd.); Skelton Grange power station, Leeds, high-pressure pipework and valves (Aiton and Co., Ltd.); Stella North power station, near Newcastle upon Tyne, ash and dust handling plant (Babcock and Wilcox, Ltd.); Stella South power station, control building superstructure (Sir Robert McAlpine and Sons (Newcastle upon Tyne), Ltd.). and ash and dust handling plant (Babcock and Wilcox, Ltd.); York power station, one 20MW turbo-alternator and feed heating plants (Brush Electrical Engineering Company, Ltd.); Roosecote power station, Barrow, ash and dust handling plant (B.V.C. Industrial Constructions, Ltd.); Daventry substation, 132kV, 2500MVA switchgear (General Electric Company, Ltd.); Clyde's Mill substation, Glasgow, site and foundation works (Holst and Co., Ltd.); Slough (New Denham) to Elstree, 275kV twin 0·4 square inch overhead line (Watsham's, Ltd.); Stony Stratford to Bedford, 132kV overhead line (Watsham's, Ltd.), and Keadby to Creyke Beck, 132kV overhead line (Riley and Neate, Ltd.).

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on or before the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., Dec. 23rd.—YORK BRANCH: Creamery Restaurant, Pavement, York, "Copper," 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Mon., Jan. 5th.—LONDON SECTION: School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1, "The Modern Single-Layer Selenium Photocell," G. A. Veszi, 6.30 p.m.

CLEVELAND INSTITUTION OF ENGINEERS

Mon., Jan. 5th.—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Operation of Blast-Furnaces at Clyde Ironworks at High Top Pressure," R. P. Towndrow, 6.30 p.m.

COMMUNICATION TRAINING CENTRE

Mon., Jan. 5th.—University College, Gower Street, London, W.C.1, day conference dealing with "Language in Presentation," "Logic in Presentation," and "The Psychology of Presentation," Reginald O. Kapp, B. C. Brookes, and A. C. Leyton, 9.30 a.m.–4.30 p.m.

ENGINEERS' GUILD

Tuesday, Jan. 6th.—W. MIDLANDS BRANCH: Imperial Hotel, Temple Street, Birmingham, "Presentation of Technical Information," R. O. Kapp, 6.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Dec. 19th.—BIRMINGHAM CENTRE: Regent House, St. Philip's Place, Colmore Row, Birmingham, "Fashion and Creative Photography in Advertising," J. Short, 6 p.m.
Thurs., Jan. 1st.—EXETER GROUP: Providence Hall, Northernhay Street, Exeter, Discussion on Home Lighting, 7 p.m.
Fri., Jan. 2nd.—BATH AND BRISTOL CENTRE: S.W. Electricity Board Lecture Theatre, Colston Avenue, Bristol, Discussion on Home Lighting, 5.30 p.m.——BIRMINGHAM CENTRE: Main Hall, College of Technology, Suffolk Street, Birmingham, Exhibition of New Lighting Equipment, 6 p.m.

INCORPORATED PLANT ENGINEERS

Thurs., Jan. 1st.—PETERBOROUGH BRANCH: Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough, Open Discussion on Automobiles, 7.30 p.m.
Fri., Jan. 2nd.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Metal Spraying for Protection," W. E. Ballard; "The Reclamation of Worn Parts by Metal Spraying," R. Wallwork, 7.30 p.m.

INSTITUTE OF ECONOMIC ENGINEERING

Sun., Dec. 21st.—Midland Hotel, Manchester, N.W. England Regional Annual General Meeting, 2.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Jan. 13th.—85, Minories, London, E.C.3, "Some Operating Experiences with Two-Stroke Cycle Engines on Boiler Oil and the Development of Fuel Injection Equipment," A. G. Arnold, 5.30 p.m.

INSTITUTE OF NAVIGATION

To-day, Dec. 19th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigation on Land," R. A. Bagnold, 5 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 30 h.—AIRPORT MEETING: Great George Street, Westminster, London, S.W.1, "The Reconciliation of Civil Engineering Problems with International Standards in the Siting and Planning of Airports," A. S. MacLaren, 5.30 p.m.
Tues., Jan. 6th.—MARITIME MEETING: Great George Street, Westminster, London, S.W.1, "The Reconstruction of Greenwell's No. 1 Dry Dock and Ancillary Works at Sunderland," Harry Ridehalgh, 5.30 p.m.
Thurs., Jan. 8th.—MIDLANDS ASSOCIATION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Prestressed Concrete in Civil Engineering Works," A. J. Harris, 6 p.m.——N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "The Management of a Railway District Engineer's Office and Some Reference to Permanent Way Design," A. L. Owen, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Jan. 5th.—S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Post-Graduate Activities in Electrical Engineering," W. J. Gibbs, D. Edmundson, R. G. A. Dimmick, and G. S. C. Lucas, 6 p.m.
Tues., Jan. 6th.—MEASUREMENTS AND RADIO SECTIONS: Savoy Place, London, W.C.2, "An Improved Scanning Electron Microscope for Opaque Specimens," D. McMullan, 5.30 p.m.——N. MIDLAND CENTRE: British Electricity Authority, 1, Whitehall Road, Leeds, 1, "Electronic Telephone Exchanges," T. K. Flowers, 6.30 p.m.
Wed., Jan. 7th.—TEES-SIDE SUB-CENTRE: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "Domestic Electrical Installations—Some Safety Aspects," H. W. Swann, 6.30 p.m.——SOUTHERN CENTRE: Technical College, Brighton, "275kV Developments on the British Grid System" D. P. Sayers, J. S. Forrest and F. J. Lane, 6.30 p.m.——N. SCOTLAND SUB-CENTRE: Caledonian Hotel, Aberdeen, "The Economics of Low-Voltage Supplies to New Housing Estates," F. G. Copland, 7.30 p.m.
Thurs., Jan. 8th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "Nuclear Reactors and Applications," Sir John Cockcroft, 4.30 p.m. Symposium of Papers on "Nuclear Reactor Instrumentation," 6 p.m.——N. SCOTLAND SUB-CENTRE: Royal Hotel, Dundee, "The Economics of Low-Voltage Supplies to New Housing Estates," F. G. Copland, 7 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Wed., Dec. 24th.—W. OF SCOTLAND BRANCH: Engineering Centre, 351, Sauchiehall Street, Glasgow, C.2, Film Night, "Pluto" and "Through the Mill," 7.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Dec. 19th.—GENERAL MEETING: Storey's Gate, St. James's Park, London, S.W.1, "Contemporary Methods of Watch Production," R. A. Fell and P. Indermuhle, 5.30 p.m.
Fri. Jan. 2nd.—GENERAL MEETING: Storey's Gate, St. James's Park, London, S.W.1, "Principles and Practice Governing Interchangeability and the Specification of Manufacturing Limits of Size as Influenced by Statistical Considerations," G. C. Adams, 5.30 p.m.
Tues., Jan. 6th.—S.W. BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Contemporary Methods of Watch Production," R. A. Fell and P. Indermuhle, 6 p.m.——LONDON GRADUATES' SECTION: Storey's Gate, St. James's Park, S.W.1, "Industrial Power Transmission Clutches and Couplings," K. J. Freeman, 6.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Dec. 19th.—NORWICH SUB-SECTION: Suckling Hall, St. Andrew's Plain, Norwich, "Planning for 5 or 250,000 Parts," R. E. Copelin, 7.40 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Fri., Jan. 2nd.—WESTERN COUNTIES BRANCH: Geology Lecture Theatre, The University, Bristol, "Unusual Design for a Large Constructional Shop," F. R. Bullen, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Fri., Jan. 2nd.—Townsend House, Greycoat Place, London, S.W.1, Film Evening, "Packaged Power," introduced by H. M. Louch, 7 p.m.
Wed., Jan. 7th.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Chairman's Address, "Some Aspects of Modern Material Handling," O. J. B. Orwin, 7 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Jan. 9th.—Mining Institute, Newcastle upon Tyne, "Marine Steam Turbines," J. Brown, 6.15 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Jan. 5th.—ORDINARY GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "The Schemes of the North of Scotland Hydro-Electric Board," W. M. Robertson, and T. Lawrie, 5.30 p.m.